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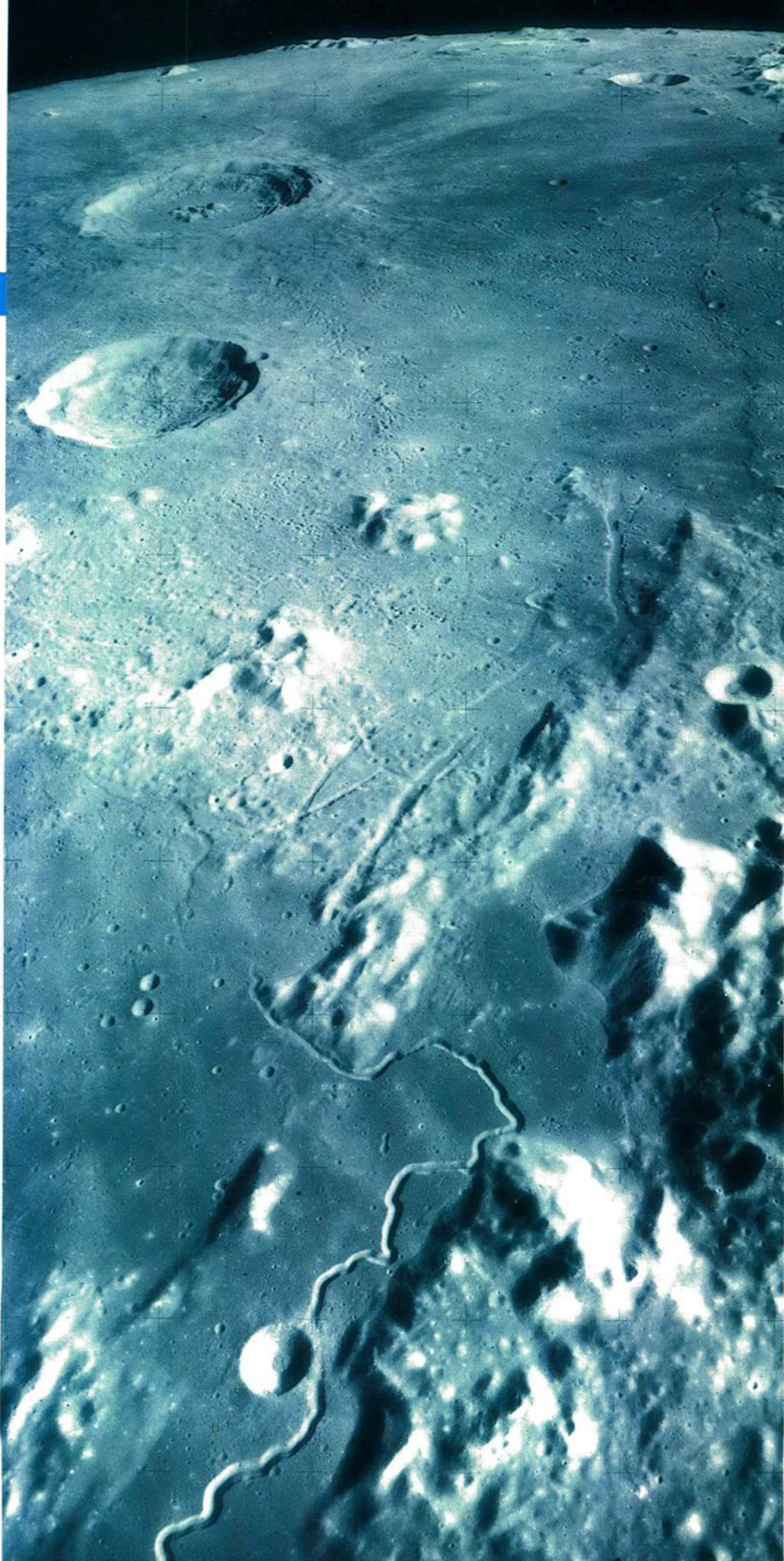
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ON THE COVER: The gravity of a black hole rips a red giant star apart, and its tattered remains help feed an ultra-luminous quasar. See page 34 for our feature story on quasars and their central black holes. Painting by Paul DiMare.

WHAT MYSTERIES LIE BENEATH THE ROCKS of the lunar Apennine Mountains? The Apollo program unfolded a pageant of lunar history — but its details remain stubbornly out of focus. See page 50. NASA photo.



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GOING FOR A HOT DECEMBER!

On behalf of the staff of ASTRONOMY and management of Kalmbach, I'd like to extend our sincere congratulations to our astronomical competitor, *Sky & Telescope*, on the completion of fifty years of publication. I first began reading *S&T* in 1958, when I was in seventh grade, and the magazine today runs on much the same philosophy as it did when I first read it. Few things in our lives remain so reliable and consistent for so long. I feel that it's an indication of the strength of amateur astronomy that this hobby can support two complementary astronomical magazines. Congratulations and best wishes on your next fifty years.

In ASTRONOMY this month, we've got a hot issue for chilly December nights. Our feature stories this month probe the edges of human knowledge; they touch on quasars, the formation of the Moon, the mysteries that amateur astronomers will investigate with the Hubble Space Telescope, and the remarkable discovery of a planet-like body found in a most unlikely place — orbiting a pulsar.

Quasars were discovered over 25 years ago, back in the dark ages when I was in high school. Although they remained one of the deepest mysteries in astronomy for decades, quasars finally make sense. As astronomer Belinda Wilkes writes, only by measuring the radiation from quasars over a wide range of wavelengths have astronomers been able to piece together a coherent picture of these enigmatic objects. Her story begins on page 34.

If you thought the Apollo program "wrote the book" on our Moon, you'd better think again. Although the Apollo moonrocks sparked the hypothesis that a collision between proto-Earth and a bigger-than-Mars proto-planet threw off the material that formed the Moon, there's still much about the Moon that remains unknown. Diamond Benningfield's account of lunar mysteries begins on page 50.

For the imagination this month, we've got a real riddle: how did a pulsar-orbiting planet — you probably heard about it on the news — survive a supernova explosion? We don't have an answer, but Robert Burnham's report on the first planet discovered outside our solar system begins on page 30.

Finally, I want to direct your attention to our review of twelve Newtonian telescopes for under \$1,000. Although we saw a few signs of poor quality control, we also found numerous quality products — and that's good news for every amateur astronomer. As Alan Dyer points out in the introduction to his story, Newtonian telescopes provide the biggest bang for the buck in amateur astronomy. His story begins on page 68.

Sincerely,



Richard Berry
Editor-in-Chief

ASTRONOMY

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Small Stars and Bright Stars

The article "The Faintest Stars" by James Kaler (August 1991 issue) states that the size of these stars may be as small as $\frac{1}{3}$ the size of Jupiter. But I thought that a star needed at least several times Jupiter's mass for hydrogen burning to start in the core. Can a star be smaller than Jupiter and yet still be several times more massive? — *Kenneth Larson, Granada Hills, California*

— Yes, because size and mass are very different quantities. The faintest stars may be as small as $\frac{1}{3}$ the diameter of Jupiter, but their mass is 60 times that of Jupiter or more. The density (the amount of mass crammed into a volume) of a star like the Sun is about the same as that of water. But the faintest stars are more efficient at packing mass into their volumes and have densities perhaps 100 times greater than the Sun's. This enables the star to be smaller than Jupiter but still have sufficient mass for hydrogen burning to occur in the core.

In "The Brightest Stars in the Universe" (May 1991), the distances listed for the stars HD 93129A and Eta Carinae are different, yet the two stars were formed within the same region. What should their distances be? Also, it is stated that Deneb loses the equivalent of the mass of the Sun every 3 billion years. But the star won't live that long! Should this be 3 million years? — *Glenn Goninan, Dubbo, Australia*

— The two stars were formed in the same region and should have similar distances. As is often the case, however, the distance to these stars is not well known and estimates range from 8,000 to 12,000 light-years. The confusion about Deneb's mass loss results from the preference of astronomers to list a rate — how much mass is lost per year — rather than the total mass lost over the life of a star. It may be easier to envision the mass loss as being roughly one-billionth of the mass of the Sun per year.

Police Those Star Parties

Dave Clyburn left one category out of his tongue-in-cheek Viewpoints article about observing violations at star parties (August 1991 issue): the Overbearing Observer. You're guilty if you think you know how others should best spend their observing time. Penalty: a mandatory one-night course in humility. — *T. Pengilly, Fremont, California*

Gentlemen:

I would like to say a few words about my new Genesis. I live in a relatively light polluted area, and own an 8" SCT which I have used for about two years. During this time there have been many deep sky objects which I have been unable to locate from my back yard.

I bought Genesis because I wanted a telescope that I could set up quickly to use at home on week-nights. When I began using Genesis, a few weeks ago, I was surprised to find many objects that have eluded me during the past two years. I was even more surprised when I realized that I

Genesis Owner Turned Into Zombie!

had been looking in the right places all the time. These objects showed up in Genesis, but not in my 8" SCT.

My back yard experience with Genesis encouraged me to take it to my dark sky observing site which is, at an elevation of 5000 feet above sea level, in the Sierra Nevada Mountains.

What I saw there was, in many cases, better than

photographs in magazines. I was able to resolve globular clusters to a greater degree than publications indicate.

I didn't expect Genesis to be this good. It really is better than I imagined.

There does seem to be one problem with Genesis. My short week-night observing sessions have become anything but short, and I frequently arrive at work feeling and looking very much like a zombie. I guess that no telescope can solve all of your problems. In any case, thanks for the ones you did solve.

- George N. Storm, California



Photo by Jim Ruffe

Unsolicited comments from warranty cards

- It's beautiful, from case to scope.
C.C. The Netherlands
- Fantastic! Great photo resolution, best optics ever owned and I'm a Hasselblad & Nikon fan. Now my best item.
D.B. New Jersey
- This is my 1st scope and I'm having a wonderful time finding the limits of the instrument and my locating abilities.
G.P. New Jersey
- Very pleased with your new improvements.
J.F. California
- Even though cost was more than an 8" SCT with mount, quality & convenience won out. I will only use Tele Vue optics, mount and accessories.
W.B. Indiana
- The telescope lives up to its expectation.
T.W. England
- Wanted a 2nd telescope that was portable, delivered wide fields and superb images. Genesis is all I hoped for. The sharpness is astonishing and it's very portable.
G.H. Canada
- Sold my 8" SCT looking for better images.
P.F. New York
- Fantastic! My wife could not see Trapezium etc. with old scope. Now can't get her away from eyepiece: you have right to be enthused about your product.
W.J. Canada

- I just wanted to have one excellent telescope to do astrophotography. Fantastic. Awesome.
J.J. California
- Beautiful equipment - Total satisfaction with first use. Keep up the good work.
M.C. Ohio
- I wanted a very high quality refractor. I was told by many - "This is it." This is a beautiful instrument!
M.F. Florida
- Remarkable! I always wanted a 4" fluorite refractor. Sold my (8" SCT).
T.S. Indiana
- Compactness & quality - a beautiful, fantastic instrument.
J.V. The Netherlands



- It's the best 4" refractor made.
A.A. California
- I was looking for the best first telescope I could buy. Something small. I never saw images clearer and more distinct than in Genesis.
G.D. Canada
- Genesis is the only scope in the race. I wanted the best and believe I got it.
E.S. Australia
- As the apparent equal of a (Maksutov), with the added RFT capability, Genesis is 'the', to me, obvious choice for portable astronomy. I'm completely satisfied.
R.A. Georgia
- Very Impressive - my first view was of Pleiades with a 40mm Wide Field. The observation was remarkable, crisp, bright and jewel-like.
P.L. Massachusetts

- The best on the market.
E.B. England
- I bought this telescope without having seen it in-person, based on its specification & your reputation for quality. As usual, I got more than I expected with Tele Vue products...
K.L. Texas
- My friend borrowed it & won't give it back!!
T.L. Canada
- I wanted portability and very high quality optics. I have waited many years to be able to afford this telescope, - it was worth waiting for.
P.H. Australia
- Superior to other 4" scopes on offer.
Z.V.S. South Africa
- Had SCT, poor contrast/resolution. Tele Vue just the opposite, also it's more portable.
W.S. Connecticut
- I purchased this instrument because:
1) Apo-refractor - basic design
2) Tele Vue reputation
3) Dealer owns same model
U.B. Canada
- Genesis is as good as gold...Maybe better!
F.G. California
- I compared specs of Tele Vue vs (other high performance refractors); TV best choice for \$.
R.A. New Hampshire
- Magic.
C.H. England



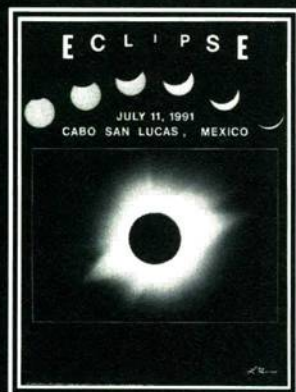
My sincerest thanks to all who've written us with such kind comments. I look forward to reading yours.

Al Nagler

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Watch Where You Drive!

How excited Jim and I were when we took our new 10-inch telescope "out" for the first time. We had used it in the driveway several times, but we had never packed up and ventured away from the house.

Planning to observe at a state park ten miles away, we loaded up the car with a few items we would need for the evening. Cramming a 10-inch telescope into a two-door car was not an easy task, and we also took a card table, two chairs, a radio, and extra clothes, not to mention coffee and dinner. Our hopes of being set up before dark were dashed when we couldn't find a suitable observing site at the state park. As night fell, we drove to the next nearest state park, which was an hour away.

This location was perfect — dark without too many trees nearby — so we unloaded our gear and thought we would eat our much-needed dinner before attempting to set the telescope up in the dark. Not too far into dinner, a very inconsiderate person drove up in a truck, shining its bright lights into our eyes. Our first observing session came to a premature end when the driver, who was evidently a park ranger, announced that we would have to leave. We were sitting in the middle of the state park golf course! — Patricia Wood, Austin, Texas

Outside the Milky Way

I have seen a photo of our Galaxy that looks like it was taken from outside the Galaxy. How can this be when we are located somewhere inside it? — Bahadır Bolukbasi, Izmir, Turkey

— We are located inside the Milky Way Galaxy but at a distance of 25,000 light-years from the center, about half-way to the estimated edge of the disk of the Galaxy. This distance is sufficient for us to see the bulge of the central regions as well as extensions that look like the arms of galaxies seen edge-on. We don't see these features in visible light because dust obscures our view. But the COBE spacecraft was able to penetrate the dust with its far-infrared camera and took the picture you mention of the inner regions of our Galaxy.

Fast Pulsar is a Bit Slower

While reading the August 1991 Astro-News article about the pulsar PSR 1512+12, I was surprised to learn that the orbital speed was listed as both one-tenth the speed of light and

900,000 mph. Since the speed of light is over 670,000,000 mph, one-tenth of the speed of light is obviously more than the 900,000 mph stated in the article.

— Michael William Messer, Tampa, Florida

— Oops! There was a typographical error in the press release we received, and we failed to catch it. The actual orbital speed of PSR 1512+12 about its companion is 450,000 mph, which is a little less than one-thousandth the speed of light rather than one-tenth the speed of light as reported.

1992 Solar Eclipse

The article "When Worlds Align" (July 1991 issue) by Alan Dyer mentions that the only landfall for the June 30, 1992 total solar eclipse is near Montevideo, Uruguay. In fact, the eclipse also can be seen from the southern tip of Brazil. In the town of Chuí (Rio Grande do Sul state), maximum eclipse will be at 11h 01m UT with an eclipse magnitude of 1.009. The duration will be 2 minutes and 20 seconds and the Sun will have an altitude of roughly 3 degrees. The duration and magnitude of the eclipse will be higher in parts of Uruguay, but the Sun will be slightly higher in the sky as seen from Brazil. — Gilberto Klar Renner, Porto Alegre, Brazil

Perseid Report

The weather in West Virginia was not very good last summer, so we were afraid we might miss the Perseid meteor shower. But the sky was remarkably clear on the night of August 12/13. We counted 102 meteors from 12:02 to 1:42 a.m. EDT at Maidsville. Two were fireballs with magnitudes of -4 and -4.5. — Kimberly A. Reedy, Morgantown, West Virginia

More Than One Way . . .

I enjoyed Stu Ekstrand's article "Raising Edmund's Astroscan" in the September 1991 issue. However, I would like to point out that using the Astroscan on a camera tripod is actually quite easy. The Astroscan's aluminum base has a 1/4-20 threaded hole in it. This lets you attach the base to any camera tripod and use the Astroscan's hallmark ball-and-socket motion. Stu Ekstrand's solution is cheaper than the heavy-duty camera tripods needed to avoid image shake. But if you already have a sturdy tripod, you can get away with no expense at all. — Sue French, Scotia, New York

The End of Civilization?

The article "The End of Civilization?" by Gerrit Verschuur (September 1991 issue) fails to mention Luis Alvarez' son. Walter Alvarez, a geologist, was the person who made the discovery of the iridium layer discussed in the story. Luis became involved in the project after the discovery. — Paul F. Johansen, Jackson Heights, New York

The photo caption on page 54 (September 1991 issue) states that the 1951 movie *When Worlds Collide* may have been inspired by the discovery of the Earth-orbit crossing asteroid Icarus. In fact, the movie was inspired by a novel of the same name and its sequel, *After Worlds Collide*, written by Philip Wylie and Edwin Balmer in the 1930s. — William Hartley, New York, New York

It is possible that the inspiration for the novel *When Worlds Collide* came from the close approach to Earth by the asteroid Eros in 1931. I remember being told as a small child in the 1930s that Eros was then the asteroid with the closest known orbit to Earth. — Fred C. Davis, Ellicott City, Maryland

Obsessed

I want to thank ASTRONOMY for reviewing our Obsession 20-inch telescope in the March 1991 issue. Alan Dyer aptly pointed out a couple of small problems that we have since addressed. The focuser drawtube has been enlarged slightly to aid eyepiece placement and a detachable Kydex light baffle that extends off the front end is now available. We've also discovered a remarkably effective cover to protect the secondary mirror — a cotton sock! — Dave Kriege, Obsession Telescopes, Lake Mills, Wisconsin

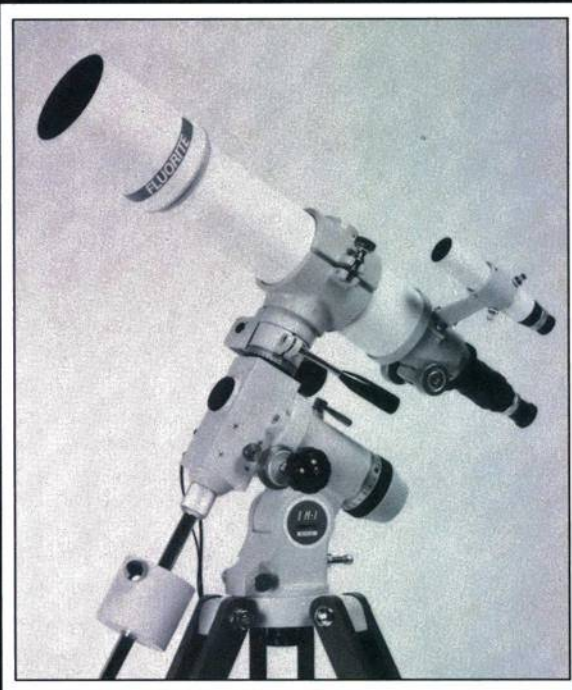
Correction

The original image used in the image processed figure on page 14 of the November 1991 issue was provided by Carey Portnoy. The 4-second exposure was taken at Ruiz, Mexico, with a 300mm telephoto lens and 2x teleconverter at f/16 on Ektar 125 film. Image processing by Richard L. Berry. □

ASTRONOMY welcomes comments, suggestions, and additional information on articles and astronomy in general. Send your letters to: ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length or clarity.

TAKAHASHI FC-76

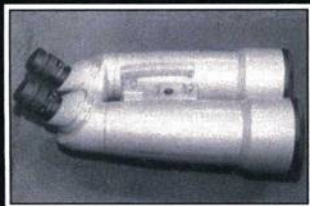
July 1991 *Astronomy* Product Review
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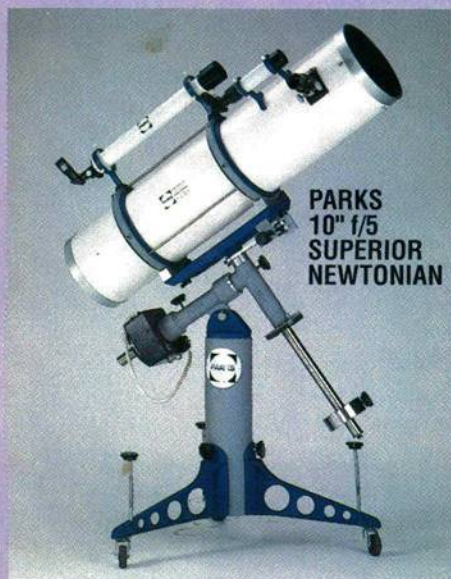
Imagine...the f/3.5 richest field telescope. Imagine observing the Veil Nebula... feasting your eyes on the North America Nebula including Mexico and the Pelican in one field of view. Imagine viewing M81 and 82, or the Lagoon and Trifid, or the entire belt of Orion, or M31, M32 and NGC 205 all at once.

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Parks proudly introduces the state-of-the-art H.I.T. telescope series. Featuring (as always) the highest-quality components, precision-crafted and assembled in-house, including hand-figured and certified fine-annealed low-expansion pyrex mirrors, genuine fiberglass tubes, dual-axis motors and drive corrector, two Gold Series 1 1/4" 5-element eyepieces and more. The telescope of tomorrow---available today!

SPECIFICATIONS OF THE H.I.T. SERIES:

Telescope	Focal Length at f/3.5	Focal Length at f/15	Factory Direct for Optical Tube Assembly Only	Factory Direct Complete System
6"	550 MM	2,300 MM	\$999	\$1,999
8"	700 MM	3,000 MM	\$1,299	\$2,299
10"	900 MM	3,800 MM	\$1,599	\$3,399
12 1/2"	1100MM	4,800 MM	\$2,799	\$5,299
16"	1400 MM	6,100 MM	\$8,900	\$15,500



PARKS
10" f/5
SUPERIOR
NEWTONIAN

Parks Newtonians Superior & Observatory Series

Superior quality telescopes featuring hand figured and certified mirrors of fine-annealed, low-expansion Pyrex. These optical systems are a product of years of design, engineering, refining, and manufacturing expertise. In a recent test, *Sky & Telescope Magazine* rated the 10" Parks mirror as the finest of the six evaluated. Quality components are used throughout these telescopes, from the genuine Parks fiberglass tubes to the dual-axis motors and drive correctors. Includes two Gold Series 1 1/4" eyepieces & a lifetime guarantee.

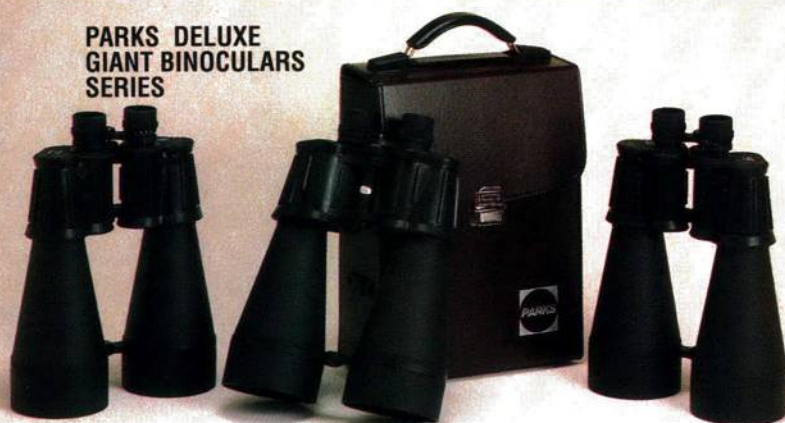
Precision Series - 6" f/6 or f/8 - \$799.00 F.D., 8" f/6 - \$1099 F.D.

Superior Series - 1 1/2" shaft mount with clock drive and dual axis drive corrector - 8" f/6 - \$2199.00 F.D., 10" f/5 - \$2599.00 F.D., 12 1/2" f/5 - \$3599.00 F.D.

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NEW!

PRT-813



From left to right: PRT-1, PRT-2, PRT-46

The Parks PRT Series

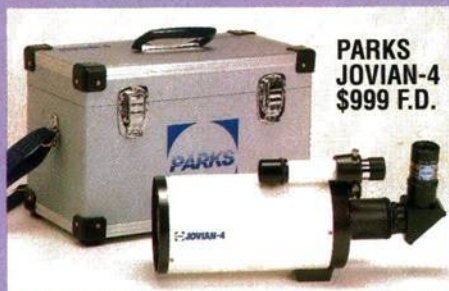
The PRT Refractor series features quality construction with a high performance 1 1/4" viewing system. Department store-type telescopes usually use the .96" eyepieces, which have smaller fields of view and inferior image quality. Parks Refractors uses sturdy metal optical tubes and fully coated achromatic objective lenses. Add a camera adapter and a t-ring and you have a powerful telephoto lens. Each PRT includes a 25mm multi-coated 1 1/4" Kellner eyepiece, a diagonal prism for a right-side up view, a sturdy adjustable wooden tripod, finderscope and a lifetime warranty.

PRT-1 - Excellent first telescope. Features a 700mm f/11.17 optical system, 60mm objective lens, 5x24 finderscope, alt-azimuth mounting - \$299.00 F.D.

PRT-2 - Same as the PRT-1, but with the addition of slow motion controls in both axes for tracking and centering objects. Also includes a built-in focusable 10X finderscope which is factory aligned and needs no adjustment - \$399.00 F.D.

PRT-46 - The finest equatorially mounted 60mm telescope in it's class. The 900mm f/15 optical assembly provides crisp, clear images even at high magnification. Includes all PRT-2 features plus: sturdy German equatorial mount with setting circles in RA and Dec, flexible slow motion control in both axes, heavy-duty adjustable wood tripod, and illuminated tripod support tray. Will accept optional electric motor drive - \$499.00 F.D.

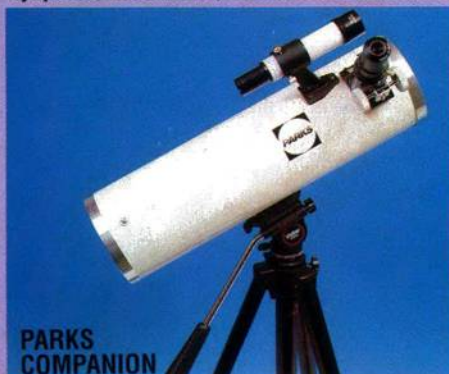
PRT-813 - The newest addition to this superb refractor line. Boasting an 80mm aperture with a 900mm f/11 optical system, the PRT-813 is complimented with a heavy-duty equatorial mount with latitude and azimuth scales, adjustable tripod, 6x30 finderscope, 1 1/4" rack and pinion focuser, and 1 1/4" diagonal prism - \$599.00 F.D.



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Parks Jovian 4

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 #55 Drive Axis Dr. Corrector Sys. 880, 1060
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 #43 R-A Drive Corrector operates from 12VDC
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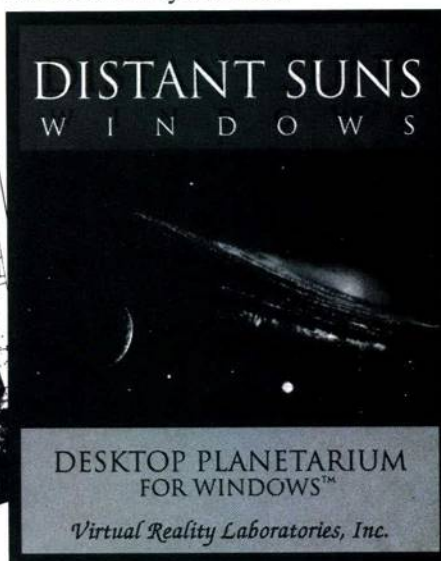
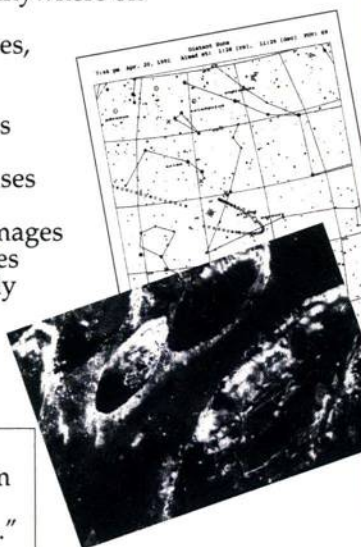
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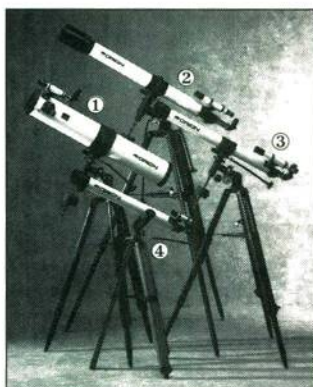
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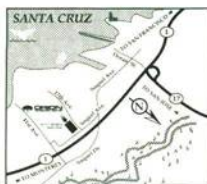


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Viewpoints

THE HIGH COST OF GETTING STARTED

by Richard E. Hill

When I read between the lines of *ASTRONOMY*'s various Telescope Buyer's Guides I find a tale of woe for the future of amateur astronomy. The type of telescopes and high prices listed in these Guides beg the questions: Where do young, budding amateur astronomers get their start? Where will future amateur astronomers come from?

I've been in amateur astronomy for 30 years. Back in 1960 my first telescope was a \$5.95 Galilean refractor of 2 inches aperture. Several years later, in 1963, I cut lawns and washed cars until I got \$30 together for a 2.4-inch Tasco refractor. By 1965 I had scraped together the down payment (after allotting a generous amount for dating) and

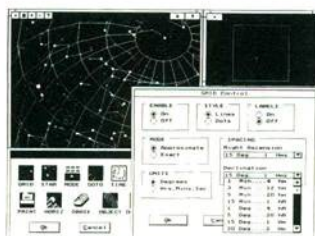
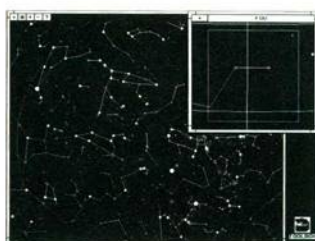


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ordered an RV-6 Dynascope, a 6-inch f/8 Newtonian. Eighteen months after delivery (which was itself four agonizing months from the time I placed my order) the telescope was completely paid off, all \$195 of it. Then, after a four-year stint in the Navy, I sold the RV-6 and bought a Tasco 4.5-inch reflector for \$110. That was 1973. At the time I needed a more portable telescope and the Tasco filled the bill.

My observing logbooks that survived from those early years show the hours of enjoyment and happy discovery I spent with the Tascos and RV-6. I was fortunate to be able to begin my astro-



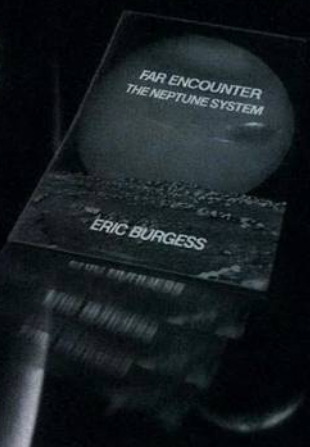
nomical pursuits with affordable, high-quality telescopes. Without the availability of reasonably priced telescopes of similar quality today how can we expect young newcomers to get into the hobby of astronomy? Many kids come from backgrounds where there is no money for telescopes. Are they to be denied access to the heavens? Will amateur astronomy become exclusively a rich person's hobby?

To illustrate my point, just look at the "sticker prices" on one of the most popular types of starter scope, the small Newtonian reflector. The venerable Tasco 4.5-inch that I paid \$110 for back in 1973 now sells for \$500. The RV-6 sold for \$200 in the early 1970s. Today's equivalent 6-inch models start at \$800. What youngster, cutting lawns, peddling newspapers, or working at some minimum wage summer job, can afford these prices? Where will they find their first telescopes?

One cannot defend the increase in prices with the argument of inflation. Since 1970, the consumer price index (CPI) has risen by a factor of three according to the *World Almanac*. Yet the price of the 4.5-inch Tasco reflector has risen by nearly a factor of five! Telescopes equivalent to my old RV-6 have gone up by a factor of 4 (and some much more). The increase in telescope prices has far outpaced inflation, especially in the last ten years. Have paper route wages kept up?

Along with today's increased prices are the disturbing reports in magazines like *Telescope Making* of a general decrease in the quality of instruments. If this is true then here is yet one more way budding observers could be turned off to astronomy. I have seen younger kids frustrated by instruments that were mechanically difficult to use or that

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produced inferior quality images. It is hard to keep youngsters interested after such an experience.

Apart from price and quality, availability is an issue. In the 1960s and early 1970s, many telescope manufacturers offered 4 1/4- and 6-inch Newtonian reflectors. Most were reasonably priced. Edmund, Criterion, Coast Instrument, Skyscope, Vernonscope, Star Liner, Optical Craftsmen, and others all had small aperture instruments available at prices within the reach of the young amateur. Companies specializing in refractors likewise offered smaller apertures at low prices. A few



of these manufacturers also had time payment plans that made telescopes even more readily available to beginners or their parents. Now there is little to none of that.

The disturbing trend toward big-price-tag, big-aperture astronomy could be countered with a return to home-made telescopes. Before the 1960s, making your own telescope was a prime choice for many people wanting to own a telescope. Today, telescope making can be divided largely into two classes: construction of exotic optical systems (i.e. tilted component systems and catadioptric telescopes of various types) or assembly of a Dobsonian telescope. The former is not for the novice. The Dobsonian revolution offers a potential solution, but has been applied mostly to large apertures of 8 inches and above. This is especially true of commercial telescopes. Further, Dobsonians, though they don't need to be, are normally of short focal ratio. The mirror is a deep parabola (hard for a first timer to make) and not well suited to general observing. An f/4 or f/5 instrument is a

specialized instrument for wide-field, low magnification viewing. They are difficult to align and keep aligned. With them, lunar, planetary, and double star observing can be very disappointing.

People wishing to make their own telescopes could benefit from low-cost telescope kits. In the late-1970s, Coulter Optical came out with a line of under-\$50 4 1/4-inch optical kits in both f/4 and f/10 focal ratios. This was a good idea. I ordered one of these and found it back-ordered for some months due, they said, to demand. If they were so popular, why were these kits discontinued? Anyone could afford one.

These days, I know some kids can afford expensive megabyte computers and other such toys, but these are not the average adolescents. For the rest of the science-minded youngsters, what the hobby desperately needs now is a manufacturer that can produce 4- to 6-inch telescope kits, or complete telescopes, at reasonable prices. But at the moment, no such company exists.

I feel that the combination of all these factors leads to a depressing sequence of events. Beginning observers get interested in astronomy. They read up and soon discover that a commercially built telescope is beyond their means. Overwhelmed by high-tech equipment ads in the magazines and big-aperture chauvinism, they begin to get discouraged. There is no build-it-yourself push to the ads any longer and few low-cost instruments. There seems to be no place to start. Slowly, a feeling of frustration sets in and interest wanes.

Nowadays no kid will be satisfied with having to save for years to get a first telescope. I know because I have seen this happening in the year or so that I have been working at the Tucson Children's Museum. If amateur astronomy is to grow, there needs to be a revival of the manufacture of low cost, small aperture instruments.

If this does not happen, a large segment of our society will be left out of astronomy, not because the hobby is not being promoted but because fewer and fewer people can afford to be in it. The universe is there for all to enjoy. Manufacturers need to make it accessible by producing a better selection of starter telescopes at a lower cost.

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by Larry Harrison

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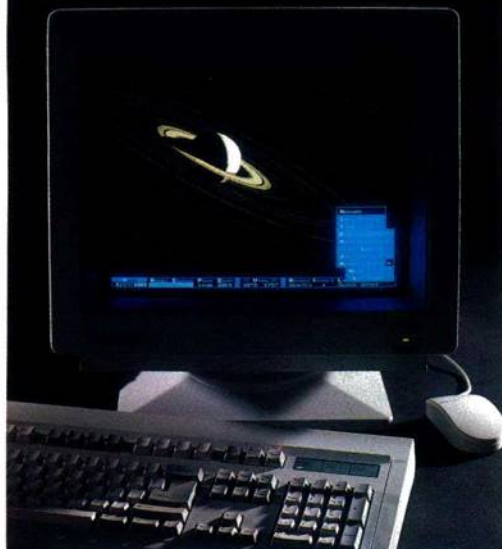
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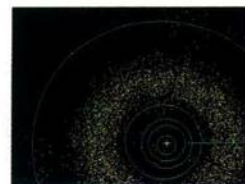
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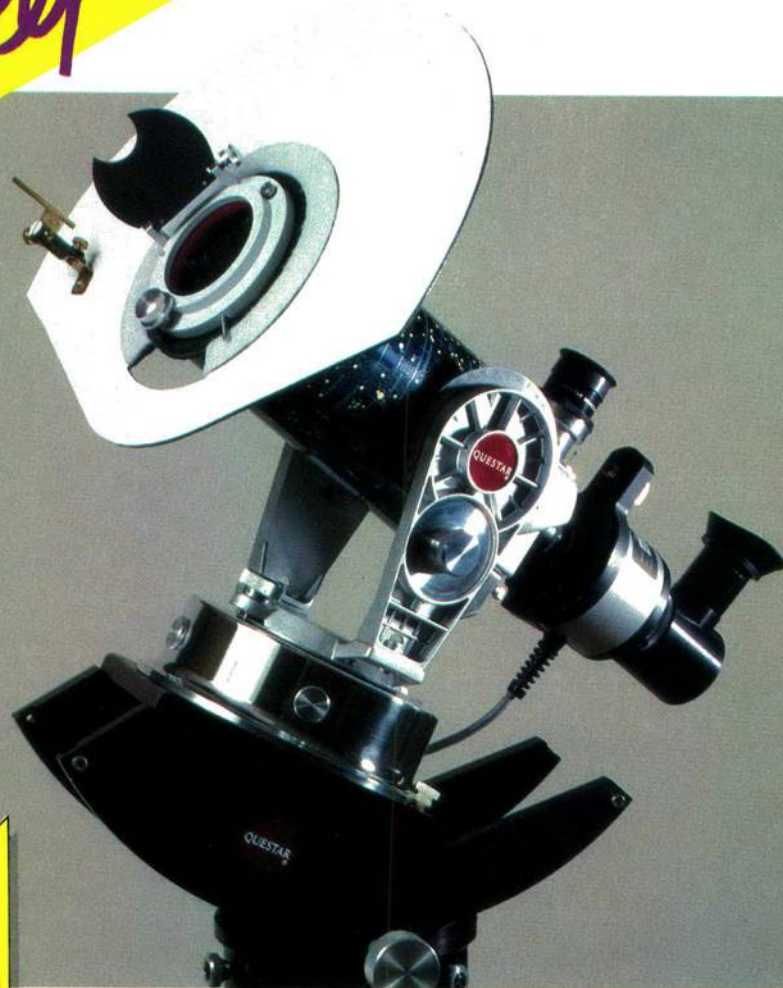
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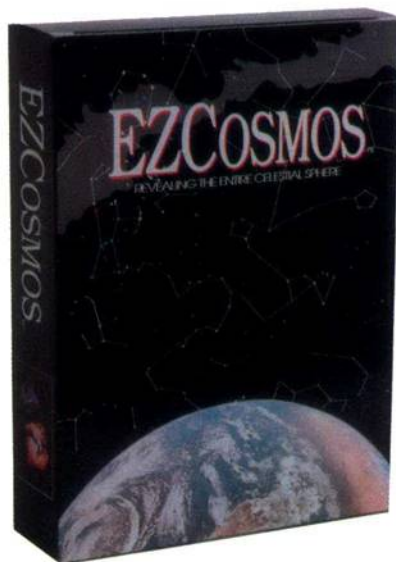
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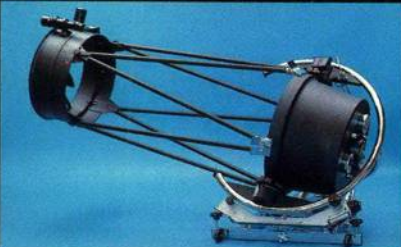


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about the rings of Saturn? Or when the true concept of the vastness of space became clear? You were probably awestruck. I know I was.

I had been told about the planets in school. I knew that Earth revolved around the Sun, and that the Sun was only one of the many stars in sky. But it wasn't until that first look at Saturn through a telescope that it all came together for me. There is a dramatic difference between being taught something from a book (and being told it's true), and experiencing it first hand.

I will never forget that rush of excitement and the thrill of discovery I felt the first time I saw Saturn through a telescope. I was 25 years old, a grown man (or at least I felt like one) with two young children of my own. While strolling through the mall with my wife one afternoon, I caught a glimpse of a short, fat little telescope in the window of a local camera store. (It was a Celestron C90.) I had seen this unusual looking telescope advertised in outdoor magazines.

The ads said it could be used for spotting game, taking pictures, or looking at the stars. I paused, staring at the scope for a moment, then finally asked the attendant if I could look through the telescope at something in the mall. He obliged. Well, needless to say that was where it all started. Just one look was all it took!

After the initial moments of excitement, I started asking the attendant all he knew about telescopes. He told me that if I mostly wanted to look at stars, I should get a different scope than the one I was looking at. He suggested a Celestron 4.5-inch reflecting telescope on a German equatorial mount. This was my day! With Father's Day just around the corner, my wife bought the telescope for me.

I could hardly wait for that darn Sun to set so I could use my new telescope for the first time. Every five minutes I would run outside to see if there were any stars out yet. Then, finally, one appeared!

I ran back into the house to get the telescope. Hurrying, I brought it outside and set it so I could see the star. I centered the star in my finderscope (which I had spent the day aligning while looking at birds) then went anxiously to the main eyepiece. There it was — a blurry image of a star. The excitement grew as I started to adjust the focus. Then suddenly, the image looked as if it had a black spot in the center of it. (It's important to know that this was my first ex-

perience with a reflecting telescope and I knew nothing about the central obstruction.) My excitement quickly changed to disappointment.

Was there something wrong with the telescope? I continued to adjust the focus. The blur with the black spot got smaller and smaller until the black spot disappeared. The excitement returned. After I adjusted the focus even further, the star seemed to flatten out and elongate. Disappointment once again came over me. There must be something wrong with this telescope, I thought. But I persevered, continuing to adjust the focus even more.

Then it happened! With a snap the image popped into focus. It was Saturn! The most magnificent sight I had ever set my eyes upon. It was right there. Right in my eyepiece. Not a picture in a book, not a story from a teacher. It was real and right in front of me. I jumped into the air, screamed for my wife "Come look!" then ran in the house to get her. The uproar I was causing brought all the neighbors out of their houses as well. Of course I shared this experience with them, too.

That was first light for me. Now I own a 20-inch reflector and just can't get enough of star gazing. I will never forget that day or the feelings that came over me. But just think, what if Saturn had not been the first "star" out that night. What if instead, my first look revealed only a star? Then my second and third attempts yielded the same? Chances are that I would have become bored with astronomy, packed away the telescope, and never used it again.

I'm grateful that's not what happened. But I'm sure it must happen to people everyday. There must be thousands who buy telescopes before they even know what there is to look at. Unless they are as lucky as I was, I'm willing to bet those telescopes are packed away in closets right now.

Every time a child (or adult for that matter) steps up to the eyepiece of my telescope and gasps, I remember my first view and the feeling I got that night with Saturn. So come on, turn a friend on to astronomy. Share in those first wonderful memories and re-spark some of your own. There are very few things in this world that are as rewarding as sharing that very special moment of discovery. The next time you take out your telescope, set it up in a public area and invite anyone who passes by to "have a look." It's sure to leave you with the same smile you had when you saw first light through your telescope. □

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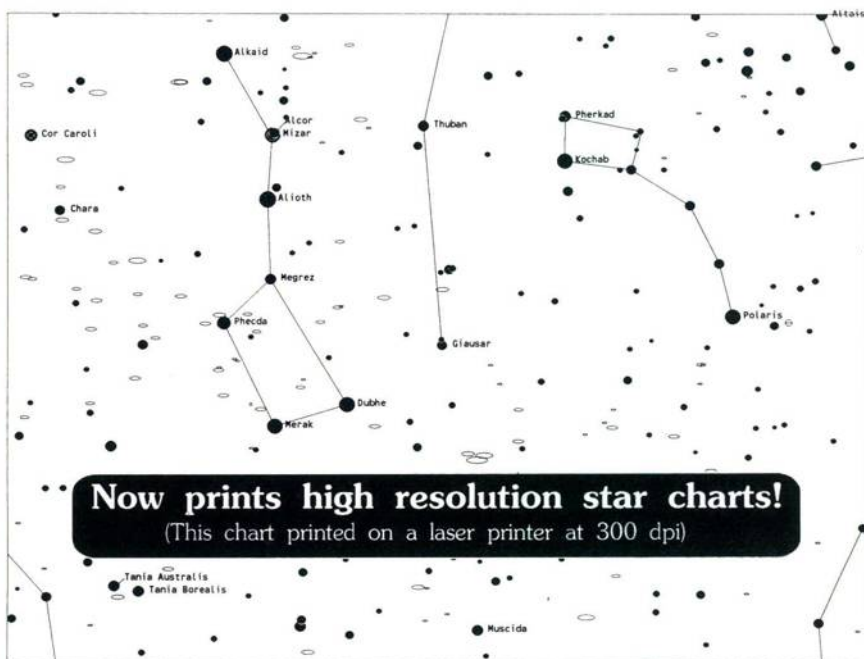
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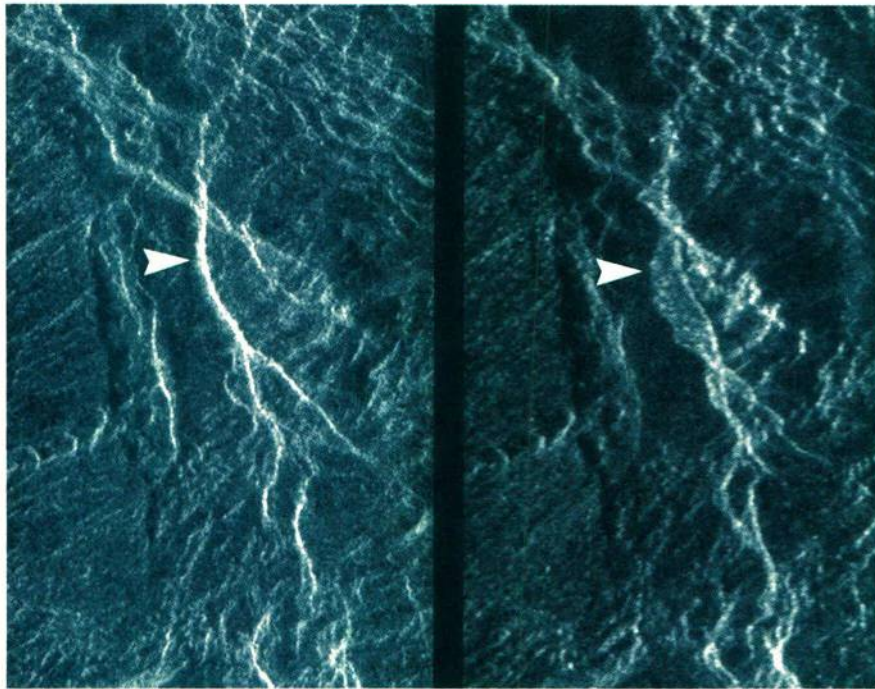
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LANDSLIDE ON VENUS — OR RADAR IMAGING ARTIFACT?



Late in August 1991, Magellan project scientist Jeffrey Plaut announced an apparent recent landslide on Venus, when a fault-cracked valley was reimaged on Magellan's second orbital cycle of the planet. The area (bright region, arrow) lies in Aphrodite Terra and measures about 2 by 8 kilometers.

Plaut, however, cautions that the landslide may simply be an artifact of the imaging system called layover. "We're now leaning toward that interpretation," he says. Magellan's radar first viewed the region in November 1990 at an angle of 45° from the vertical; its second look was in July 1991 at an angle of 25° from the vertical. Layover — a superposition of adjacent terrain — can happen when the radar imager views the same scene from two different look angles. In one image the terrain is superimposed; in the other it isn't — and comparing the two images leads to an apparent change.

To resolve the question, scientists hope to reimage the same location in February 1992 from the original view angle and thus confirm or disprove the apparent change.

NEW VIEWS OF 47 TUCANAE

Globular clusters are among the oldest objects in the universe, having formed some 12 to 15 billion years ago. And essentially all of the hundred thousand to a million stars contained in one of these huge agglomerations date from the birth of the cluster. Yet surprisingly, many globular clusters contain a population of hot and apparently young stars. What causes this apparent discrepancy? It's a question astronomers are closer to answering as a result of recent observations from the Hubble Space Telescope and the ground.

The target of these new observations is the globular cluster 47 Tucanae.

Among the more than 100 globular clusters belonging to our Galaxy, this one stands out. It is the second brightest globular in the sky (behind Omega Centauri), and lying at a distance of 15,000 light-years, it is one of the closest to Earth. Its proximity means astronomers can get a sharper view of the cluster

THE CORE OF 47 TUCANAE contains a number of stars exceptionally bright in ultraviolet light — the so-called blue stragglers. HST's Faint Object Camera captured several of these blue stragglers (the brightest objects in this ultraviolet image), which are likely binary stars that may dominate the dynamic evolution of the cluster. NASA/ESA photo.

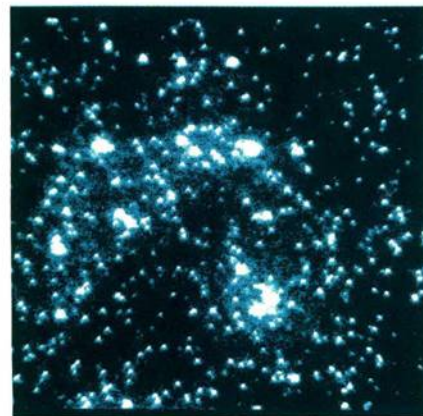
than of other, more-distant clusters.

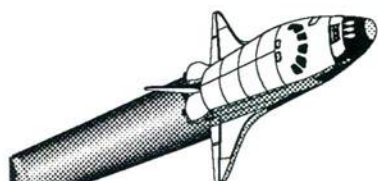
And the sharpest view yet of this cluster's dense core has come from the Hubble Space Telescope's Faint Object Camera. What HST revealed is a surprisingly high concentration of a unique class of star called blue stragglers, which are hot (and hence blue) — as if they were much younger than the rest of the cluster's stars. These stars may also play a critical role in the dynamic evolution of the cluster's core.

The researchers — Francesco Paresce, Michael Shara, Georges Meylan, and the Faint Object Camera team — took advantage of HST's high resolution and ultraviolet sensitivity to probe the dense center of the cluster, where they resolved 21 blue stragglers. "The 47 Tucanae blue stragglers are extraordinarily centrally concentrated, supportive of the view that they are the product of collisions, mergers, or close encounters among stars," said Paresce. The team reported their results in the July 25 issue of *Nature*.

Although astronomers have proposed several ideas to explain blue stragglers, the most likely seems to be that they arise when two stars encounter one another and form a tight binary system. Close encounters between stars in the tightly packed cores of globular clusters are fairly common — astronomers estimate that one out of every hundred stars in a globular cluster has had a close encounter with another star. Furthermore, most stars in globular clusters travel at relatively slow velocities with respect to one another, so a pair of passing stars feels each other's gravitational pull for a fairly long time and thus is more likely to capture one another.

If the passing stars are captured, the





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more massive, and hence faster evolving star, will eventually become a red giant and lose part of its extended atmosphere to its less massive companion. The fresh supply of hydrogen would then heat up the smaller star, making it hotter and bluer. If the passing stars instead collide or merge, the stars' nuclear fuel would mix and re-stoke the fires of nuclear fusion.

The researchers found the blue stragglers highly concentrated toward the core of 47 Tucanae, suggesting that they are significantly more massive than most of the cluster's stars — just what you would expect if they were merged stars or members of binary systems. If

many of the blue stragglers are actually in binary systems, they could help explain why the cores of globular clusters are not even more densely populated. Because the orbital motions in the binary systems are much greater than the motions of single stars in the cluster, the blue stragglers would serve as kinetic energy "batteries" and stir up the motions of thousands of other stars in the cluster, like a pair of eggbeaters.

The researchers caution that the new HST images don't prove that the blue stragglers in 47 Tucanae lie in binary systems. However, some recent ground-based observations support the view that binaries are common in this cluster.

A team of Australian, British, and Italian astronomers used the Parkes radio telescope in Australia to discover 10 millisecond pulsars in 47 Tucanae, bringing the total known there to 11. They reported their observations in the July 18 issue of *Nature*.

Of the 11 millisecond pulsars, more than half belong to binary systems. And the researchers emphasize that they probably saw only the tip of the iceberg — there are probably many times more millisecond pulsars in 47 Tucanae than they found. Although the binary pulsars and the blue stragglers found by HST form separate populations, they both point to the same conclusion — that

Amateur News

NEW ENGLAND ASTRONOMY SUMMER

Like the blossoming of complex and pretty flowers, amateur astronomy meetings sprouted in New England this summer and featured a dazzling array of talks and telescopes. The oldest and most established of these was Stellafane, held August 9-10, 1991, in Springfield, Vermont. This year's gathering was slightly downsized because many people spent their time and money to travel to Baja California to see last July's solar eclipse. Despite this circumstance and a driving rain storm on the convention's first night, Stellafane, the king of amateur astronomy conferences, offered a splendid chance for amateurs to come together and talk about their hobby.

Preceding Stellafane this year was the Astronomical League's ALCON 1991 gathering, held from August 6 to August 9, in Amherst, Massachusetts. The event was hosted by the Amateur Telescope Makers of Boston. Altogether, nearly 150 people assembled at the University of Massachusetts to hear a wide variety of speakers. Among the most unusual talks were those by ASTRONOMY's Richard Berry and *Sky and Telescope's* J. Kelly Beatty concerning how these magazines are produced and what types of information they will provide in the future. Berry also delivered a detailed account of CCDs in amateur astronomy, accompanied by a series of illustrations showing the techniques of image processing.

Daniel W. E. Green of the International Astronomical Union's Bureau for Astronomical Telegrams described the

current state of astronomical discoveries by amateurs. After detailing a long list of activities in which amateurs play an important role — including the discovery of comets and observations of meteors and asteroids — he suggested that amateurs could make even more substantial contributions to scientific data-gathering in the future by submitting their observations to the Central Bureau.

High resolution photography and CCD imaging of planets constituted the focus of Don Parker's presentation. Parker, a resident of Coral Gables, Florida, has over the past several months applied his expertise with normal planetary photography to CCD imaging, producing some of the most impressive images of planets ever taken by backyard astronomers. Examples of his Jupiter images appeared in ASTRONOMY's Reader Reports for June and September 1991.

CCD imaging was also the topic of Rudolph Schild of the Harvard-Smithsonian Center for Astrophysics. Schild's keynote address included a presentation of many of his images of galaxies made with large observatory telescopes. Cautionary about image processing, however, Schild emphasized that achieving a "natural" color palette is important so that CCDs show the universe as it is rather than in an exaggerated state of artificial colors.

On August 9 virtually all of the ALCON attendees made the trip north to Stellafane. The weather on Friday afternoon appeared threatening, and by the time amateurs covered Breezy Hill

in Springfield on Friday night, a torrential downpour started. Little happened on Friday save for the few dozen people who crowded into a tent to hear the somewhat desperate attempts at delivering Stellafane's traditional Friday night tent talks. Taken overall, however, Friday night was a washout.

Saturday morning brought hope. The sky was overcast but the rain had stopped, and aside from great swaths of mud the situation was normal. Stellafane's traditional morning swap meet offered the chance to pick up a used eyepiece, surplus lens, mirror blank, or back issues of magazines cheaply. Many transactions took place. During the afternoon the sky partially cleared and eager amateurs set up telescopes on the hill's summit and looked forward to the possibility of clear skies at night.

As evening fell on Breezy Hill, a silent crowd ringed the hillside in what has become the convention's outdoor amphitheater to listen to the traditional "shadowgram" given by veteran deep-sky observer Walter Scott Houston. Afterward, Sam Palmer of the Harvard-Smithsonian Center for Astrophysics delivered a talk on the current state of meteorite science. As he spoke, the crowd was able to watch an unusually active Perseid meteor shower send golden streaks overhead, sometimes as many as a few per minute. After a hesitant start, Stellafane turned out all right.

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Astro-Physics



Photo by Tony Hallas and Daphne Mount
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TECHTALK What is a high resolution lens?

We define it as an object glass that focuses a large portion of the visible spectrum (C to F wavelengths) into a tight spot smaller than the Airy disc (approximately 10 microns for an f8 lens). It also must focus the photographic spectrum (R to G wavelengths) into as small a spot diameter as possible across a large field. The 5" f8 lens is capable of 40 micron spot diameters at the edges of a 2.5°, 3.6 degree field. This gives the lens the ability to capture very tiny detail on fine grained film that can then be enlarged to poster size without fuzzing out. It also allows the lens to be used as a high power planetary telescope, fully capable of resolving low contrast planetary detail without resorting to filters.

To achieve this level of performance requires high surface accuracy. Instead of fancy aspherics, the StarFire lens uses an all spherical design to achieve spherical aberration correction and negligible sphero-chromatism. This assures the smooth surface profile so important to crisp image detail and high contrast. Surfaces are checked by test plate interferometer methods, and the final figure and color correction is verified on a double pass autocollimator. Because of the all spherical design and our ability to test each surface separately, we can guarantee a high resolution lens every time.

This stunning photograph of the Pelican Nebula in Cygnus was taken with our 5" StarFire on the 800 mounting. Guiding was done with a separate 3" guidescope. The Pelican area shown above is approximately 1/3 of the original 6 x 7 format. This reproduction can only hint at the incredible detail visible on the full negative. Tony remarked that even in 16 x 20 enlargements, the smallest stars remain only pinpricks, and some close doubles require a 40" print to adequately resolve. This is only one of many photos that we have received from Tony that show the level of detail that a precision lens can record on hypered fine grain film.

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binary stars have played and will continue to play a major role in the evolution of 47 Tucanae. Now the question is whether the same holds true for other globular clusters. You can bet astronomers will step up their observations of globulars to try to pin down the answer.

NEW EVIDENCE FOR GALAXY CLUMPING

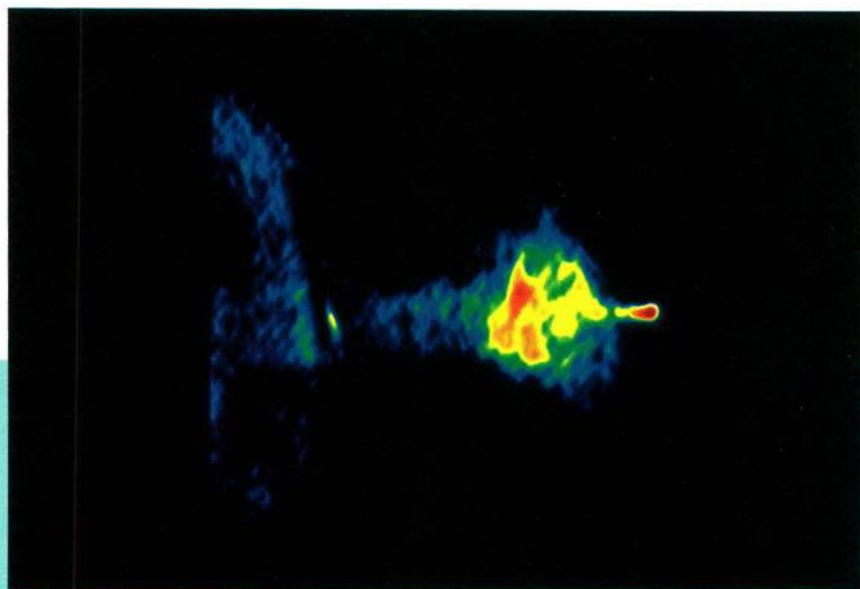
Galaxies gather in clusters, and clusters gather in superclusters. Though astronomers have recognized this hierarchy for many years, they still don't know just how clumpy the universe really is. Now, new research shows that the universe is more clumpy than previously thought and perhaps more clumpy than our current cosmological models can explain.

Alain Picard of Caltech reports in the August 1991 issue of the *Astronomical Journal* that the number of galaxies in two large and widely separated regions

of the sky differ markedly. Using data from the ongoing second Palomar Observatory Sky Survey, Picard counted galaxies in two regions: one in Corona Borealis in the northern galactic hemisphere and the other in Pisces in the southern galactic hemisphere. If the universe were homogeneous, these galaxy counts would have revealed roughly equal numbers of galaxies, differing by no more than 3 or 4 percent. Instead, the northern region held 30 to 40 percent more galaxies than the southern one.

"We've known for a long time that

the distribution of galaxies in the universe is not random," said Picard. "The interesting question is: How nonrandom? My research indicates that the universe is even more clumpy than indicated by previous work. This study adds strong support for previous findings that galaxies are assembled into very large-scale structures, structures whose existence cannot be explained by our current cosmological models." Now it's up to the theorists to try to explain the origins of the structure observers are continuing to find.



RAPIDLY MOVING YOUNG PULSAR

Astronomers report in the August 29, 1991 issue of *Nature* a link between a pulsar and an enigmatic fan-shaped nebula that emits radio waves. New observations of the nebula, G 5.4-1.2, taken at the Very Large Array (VLA) radio telescope near Socorro, New Mexico, by Shrinivas Kulkarni (Caltech) and Dale Frail (National Radio Astronomy Observatory) identify the nebula as a supernova remnant. The pulsar, PSR 1757-24, appears to be moving through the shell of debris created during the violent explosion that formed the pulsar.

Supernova remnants are formed during the final stages in the life of a massive star. As nuclear reactions in the core of the star become unstable, the star explodes, ejecting its outer layers into space to form the supernova remnant. The core remains as a compact neutron star, which sometimes is seen as a pulsating source of radio waves, or pulsar.

The peculiar shape of G 5.4-1.2 and the fast speed of the pulsar — estimated to be 2,000 kilometers per second — suggest that the supernova collapse that gave rise to the remnant and pulsar was asymmetrical. A symmetrical collapse and explosion would result in a twisted and knotted shell of gas surrounding the pulsar, as seen for the Crab Nebula and pul-

A PULSAR SPEEDS THROUGH THE GAS of its associated supernova remnant leaving a trail of emission behind it. The pulsar, PSR 1757-24, is located in the red-colored knot seen at the right edge of the image. Courtesy of the National Radio Astronomy Observatory.

sar. However, an asymmetric collapse would result in an explosion which would "kick" the pulsar away from the original position of the star.

In the explosion that likely created PSR 1757-24, the outer layers of the star initially moved away from the explosion site at speeds of 5,000 kilometers per second or more while the part of the core that became the pulsar moved away more slowly. As the gaseous shell of the remnant expanded, its speed eventually slowed and the once-brilliant gas faded in brightness. As captured in the VLA observations by Kulkarni and Frail, the pulsar still moving at a speed of 2,000 kilometers per second has finally caught up with the now slow-moving shell and passed through it, rejuvenating emission in the supernova remnant.

PSR 1757-24 is one of the youngest pulsars yet discovered in our Galaxy. The pulsar's age has been determined from the change in its rotation rate since its discovery in 1982. Pulsars spin more slowly as they age, and young pulsars slow down more slowly than older ones. Kulkarni and Frail's measurement of the pulsar's rotation rate places the age of the pulsar at 16,000 years.

Asymmetrical collapses may explain why so few pulsars are seen in the vicinity of supernovae remnants. In order to dismiss other possible explanations for the evolution of the system, Kulkarni and Frail hope to make direct measurements of the pulsar's speed. "Luckily, the VLA is up to the task," said Kulkarni. "We should be able to actually see the pulsar move over the course of a few years."

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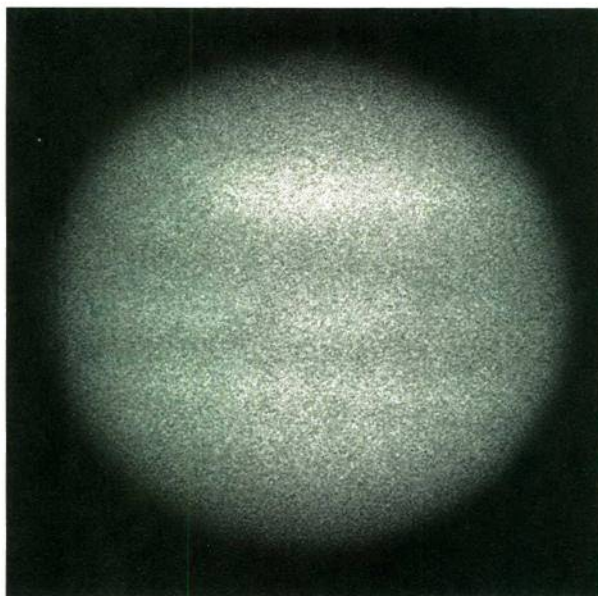
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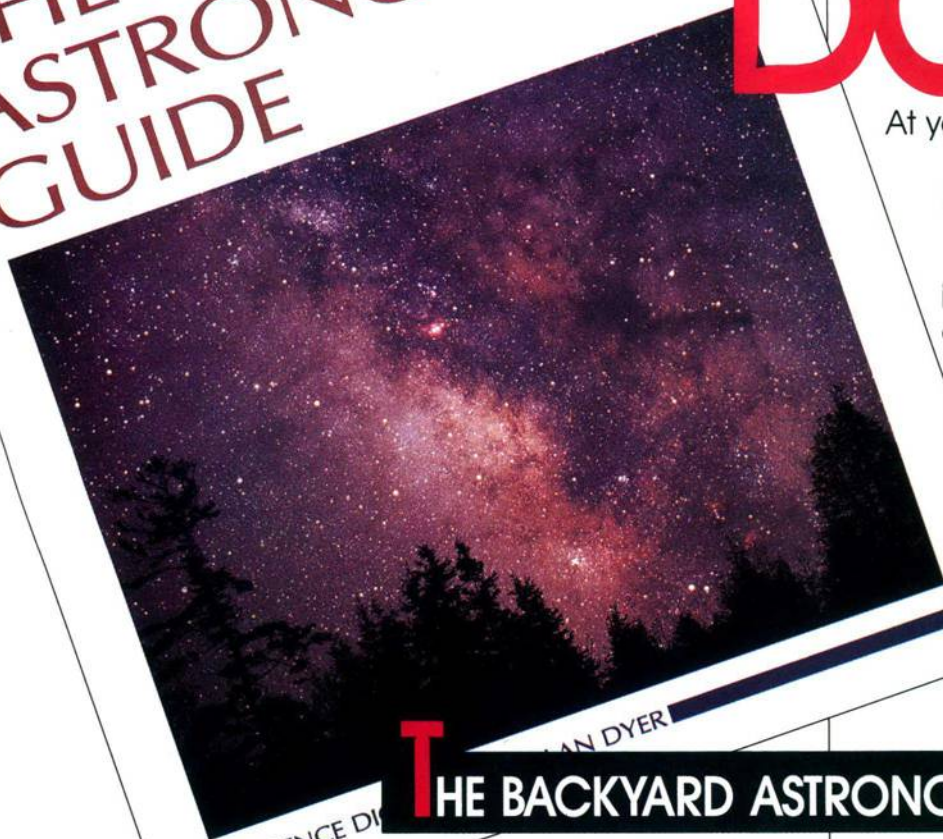


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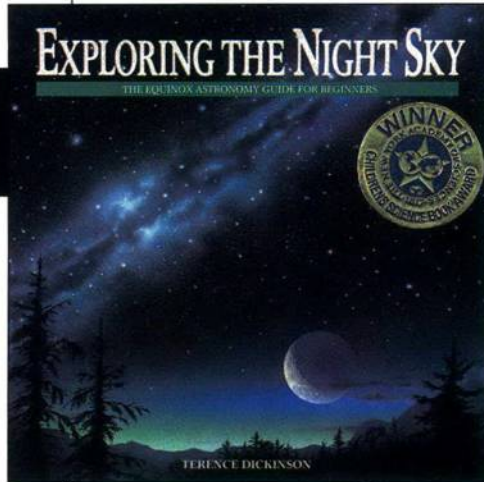
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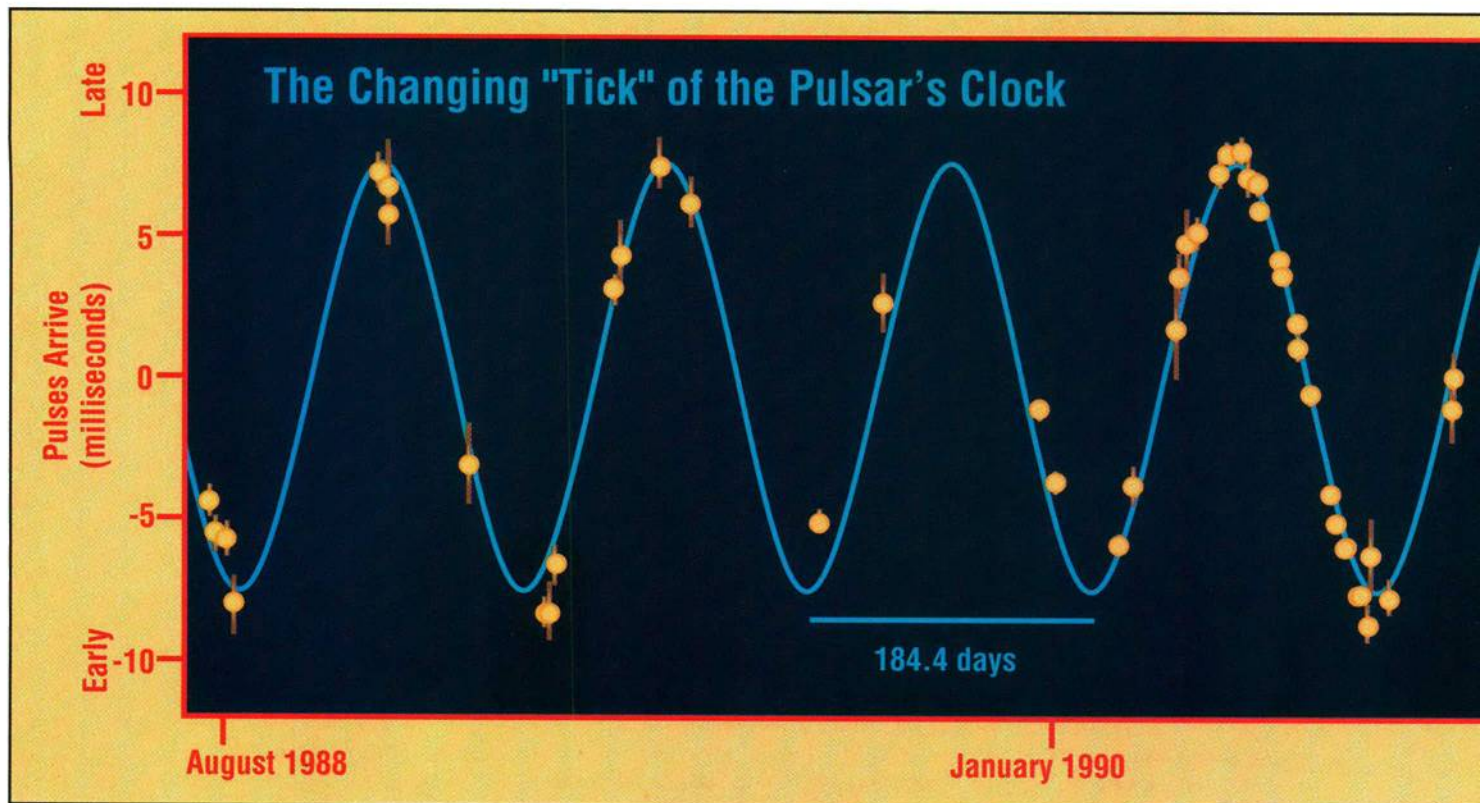
FIREFLY BOOKS

The **F**irst **P**lanet **B**eyond the **S**olar **S**ystem

Radio astronomers have found a pulsar whose variable timing can be explained by a Uranus-sized world orbiting the star. Its nature is unknown, but whatever that turns out to be, the object's mere existence poses major challenges to theorists.

BATHED IN EERIE RADIATION, the glazed landscape of the possible new-found planet sprawls before its sun — a supernova-remnant pulsar — in this imaginary view. Painting by Bob Eggleton.





If three British astronomers are right, they have discovered the first planet outside the solar system. The irony is that the planet wasn't found the way everyone expected it would be.

No orbiting speck of light reflected the glare of its star — and certainly no mysterious geometric patterns concealed in radio codes or old "Honeymooners" programs came beaming back from some distant civilization. Instead, the object was found by regular changes in the electromagnetic "ticking" emitted by its home sun, a pulsar only 30 kilometers across.

The story of this enigmatic object began in 1985, when astronomer Andrew Lyne discovered pulsar 1829-10 in a survey that also uncovered 39 other pulsars. (Pulsars are neutron stars, the super-dense remnants of large stars that have exploded as supernovae. Spinning rapidly, pulsars emit regular flashes of energy, hence their name.) Invisible at optical wavelengths, pulsar 1829-10 lies near the galactic equator in Scutum at a distance of roughly 30,000 light-years.

Over the past six years Lyne and coworkers Matthew Bailes and Setnam Shemar of the University of Manchester have used the 250-foot Lovell Radio Telescope at Jodrell Bank, England, to make regular observations of this pulsar and the others. They timed 1829-10's pulses —

which recur every 0.330354 second — with great accuracy.

"The pulses of most pulsars are like the ticks of a very good clock," says Lyne. "And we can usually model their slowdown quite accurately." But not 1829-10. "For this particular pulsar, we found departures from a simple slowdown model and fluctuations in the pulsar's apparent period." They found that after they made all the necessary corrections, there remained small, unaccounted-for variations in the pulses' arrival times. Astronomers call such leftovers residuals.

In 1987 Lyne kicked the observations of 1829-10 into high gear. With improved data from intensive observations, the team plotted the timing residuals and found that they varied every 184.4 days in a highly regular manner (see the graph above).

"We found that on a 6-month cycle the pulses were arriving early or late by about 1/100th of a second," remarks Lyne. "We attribute this to the pulsar moving toward us or away with a maximum velocity of about 3,000 kilometers per second."

After eliminating possible causes within the pulsar itself, Lyne says, "the most straightforward interpretation was that some unseen, small body was orbiting the pulsar and tugging on it with its gravity."

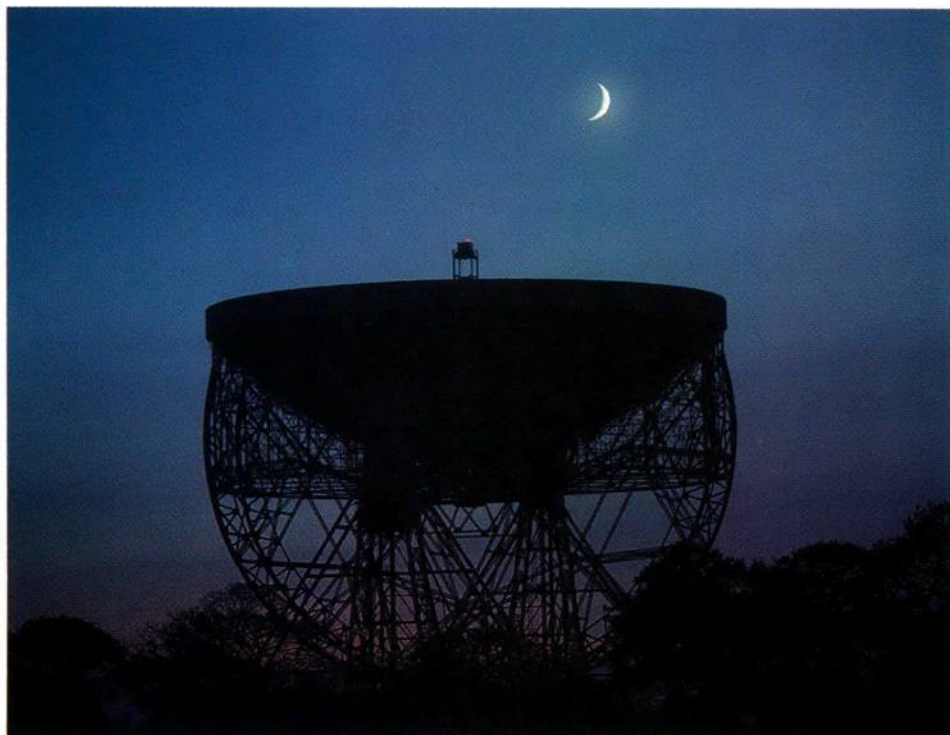
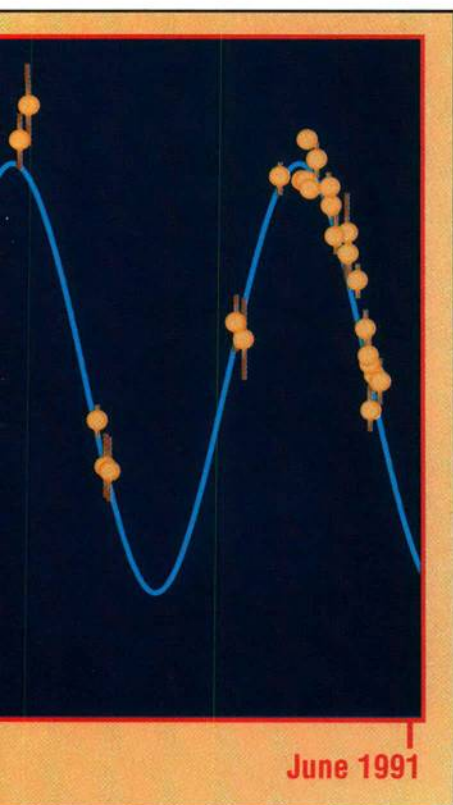
When the astronomers assumed

the pulsar had a mass 1.4 times that of the Sun (a likely value), celestial mechanics yielded a probable mass for the unseen object of 10 to 15 times that of Earth and a nearly circular orbit at a distance from the pulsar of 0.71 astronomical unit. In solar system terms, this is roughly comparable to a Uranus (14.5 Earth masses) orbiting at Venus' distance from the Sun (0.72 AU).

But the planet almost certainly wouldn't *look* like Uranus — or any other planet familiar to us. As Lyne says, "If the object lies in the beam from the pulsar, the surface temperature there might not be unlike Earth's, and the total radiation falling on the object would be about what we get on Earth. But the radiation is in the form of gamma-rays and charged particles."

Would life be possible? Although he can't absolutely rule it out, Lyne is highly skeptical. "I think that it's very unlikely there is any life form on this planet. The main reason is the powerful radiation from the pulsar. There would be so much 'hard' radiation and so little light as we think of it. I believe that any form of genetic material would be destroyed."

But behind the details lies a larger issue. How did the planet survive the supernova explosion that turned its star into a pulsar? Lyne himself is puzzled: "We were quite



surprised to find a planet orbiting a neutron star because a neutron star's formation is thought to result from a supernova explosion. During this explosion, a lot of the star's mass is lost. This is the main hazard the planet must survive. If more than half the star's mass is lost, the system becomes unbound and the planet will go shooting off.

"As far as the explosion goes, it's possible that the planet would absorb a substantial amount of energy from the blast wave. But the effect should be small — the planet might lose its outer atmosphere. Yet I think a planet would almost certainly survive the explosion."

Moreover, adds Lyne, "it may be that not all neutron stars form in such a violent process; there could be an as-yet unknown gentler way. Or perhaps the planet formed *after* the explosion from debris in the vicinity."

Another mechanism, recently advanced by Cambridge University astronomers Ph. Podsiadlowski, J. E. Pringle, and M. J. Rees, proposes that the planet is the outcome from either of two processes. In the first mechanism, two white dwarf stars merge to form the pulsar and the planet condenses out of a massive disk of material left over. In the second method, a neutron star collides with and cannibalizes the central star of a solar-type planetary system. The orbits of the inner

planets are disrupted, but stabilize again as they orbit through a short-lived envelope of gas surrounding the disrupted central star.

When the report of the pulsar's planet appeared in *Nature*, Columbia University astronomers David Helfand and Thomas Hamilton quickly replied to it by disputing that the object is orbiting the pulsar and suggesting that maybe it's not a planet either.

Made suspicious by the object's neat 6-month period, Helfand and Hamilton argue that the timing delays could be explained by a small cloud of ionized gas, about one AU in size and lying stationary in interstellar space relatively near the Sun. They claim that this could introduce a 6-month period of variation in the timing as our line of sight to the pulsar, constantly moving throughout the year, passed through different parts of the cloud with varying thicknesses.

Lyne replies that such a cloud would give markedly different velocities for the object when the pulsar was viewed at different radio frequencies; in fact, the observed velocities are virtually identical. Second, he notes that such a cloud of ionized gas should be easily detectable by its hydrogen-alpha emission and this has not been observed.

If pulsar 1829-10 has one planet, could it have others? Lyne and his

NOW IT'S EARLY, NOW IT'S LATE. A 6-month variation in the timing of the pulsar's signals (left) tipped off three British astronomers that a planet-sized object was orbiting the star. They used the 250-foot Lovell Radio Telescope at Jodrell Bank, U.K. (above).

group don't know, but they point to the fact that there are changes in the plot of residuals. (You can see a hint of these if you lay a straightedge along the data points at the extremes of the curve.)

These deviations from a perfectly repeating path create a second level of residuals that might indicate the pulsar has other gravitating bodies in orbit around it with different periods. The team intends to continue observing the pulsar in hopes of getting enough data to disentangle any overlapping periods and resolve this question.

The Case of the Pulsar's Planet is far from solved. Other astronomers are scrambling to confirm the observations, add their own data, and contribute ideas to the puzzle. But whatever the outcome, pulsar 1829-10 has a lot of new things to teach us. □

Robert Burnham, with contributions from Barkat Sorathia of the University of Newcastle upon Tyne, United Kingdom.



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The Emerging Picture of Quasars

Radio, infrared, ultraviolet, and x-ray radiation from quasars shows that they are supermassive black holes surrounded by a thick disk of dust and gas.

by Belinda J. Wilkes

Quasars are the brightest objects in the universe. From a volume perhaps no larger than our solar system, as much light as a trillion Suns pours forth. These enigmatic objects have continually fascinated, puzzled, and surprised astronomers during the 28 years since they were discovered. Recently, observations at wavelengths across the electromagnetic spectrum and advances in instrumentation have given us a more complete view of quasars and a much better understanding of what they are and how they work.

A Puzzling Discovery

As is often the case in astronomy, our first view of quasars was misleading. In 1963 astronomers discovered two strange radio sources — unusual in that they were strong, small, and varied rapidly — during the course of the 3rd Cambridge (3C) radio survey. Optical photographs of the regions surrounding both 3C 48 and 3C 273, as they were called, showed only an innocent-looking blue star. Because no stars known at that time could emit so much radio radiation, astronomers seemed to have a new and very unusual kind of star on their hands.

Optical spectra of the objects, however, taken to find out what kind of star they were, looked nothing like that of a star. Strong, broad emission lines, unlike any seen previously, dominated the spectra, instead of the usual narrow absorption lines. After puzzling over this spectrum for a while, Maarten Schmidt of Caltech realized that the emission lines were the familiar Balmer series of hydrogen lines shifted to longer (redder) wavelengths. The amount of this redshift implied that the stars were moving away from us at high velocities (for 3C 273, 16 percent that of light). This velocity was much faster than that of any galaxy known at that time and seemed unlikely for a star!

Astronomers developed two main theories to explain the high velocities of quasars. In the ejecta model, strong explosions eject quasars from nearby stars or galaxies. In the cosmological model, quasars

are simply very distant objects taking part in the general expansion of the universe. (This is called the cosmological model since cosmology is the study of the universe itself.) Astronomers already knew from galaxy observations that objects at greater distances from Earth appear to be moving away at greater speeds. In the cosmological model, the quasars simply extend this relation to greater distances (about 3 billion light-years for 3C 273).

The large distances implied by the second alternative means that quasars must be extraordinarily bright to be seen from Earth. Not only this, but the short timescale of the radio variability implies that some quasars are only about 1 light-day in diameter, or roughly the size of our solar system. In 1963 no mechanism was known that could generate so much energy in such a small volume, and as a result astronomers were generally reluctant to accept the cosmological picture of quasars. Regardless of the correct model, the name "quasi-stellar radio source," since they look like a star but are in fact very different, was born and the variants "quasar" and "QSO" are the names generally used today.

The search was on! As astronomers looked for objects with matching radio properties, they found more and more quasars. However, they also found many similar objects that emitted little or no radio radiation. In fact radio emission turned out to be the exception rather than the rule with quasars — only about 10 percent of all quasars are strong radio emitters, roughly the same proportion as in galaxies.

The next advance came when astronomers examining detailed photographs found that many quasars had a fuzzy appearance around the bright central object. The spectrum of the fuzz appeared similar to that of a galaxy at the same redshift as the quasar. Thus quasars seemed to lie in the central regions of galaxies but, because they were so much brighter than their host galaxies, fuzz could only be seen in those closest to Earth. They are also frequently situated among groups of galaxies at similar redshifts.

The evidence linking quasars to galaxies supported the cosmological model for quasars. At the same time, no quasars had been found with blueshifted emission lines indicating that they were moving toward us rather than away. Because the

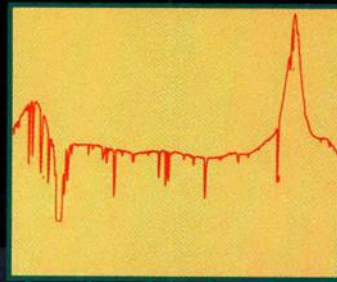
BRIGHTER THAN A TRILLION SUNS, a quasar's central engine dominates the view from the outskirts of its host galaxy. Illustration by Michael Carroll.

SPECTRAL OBSERVATIONS

X-ray

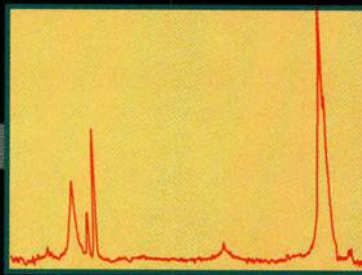


Ultraviolet



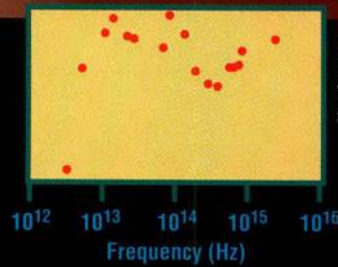
Detailed ultraviolet spectra of quasars are now possible with the Hubble Space Telescope.

Optical



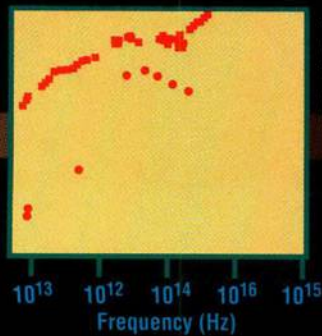
A typical quasar's optical spectrum shows the strong, broad emission lines that characterize quasars.

Infrared

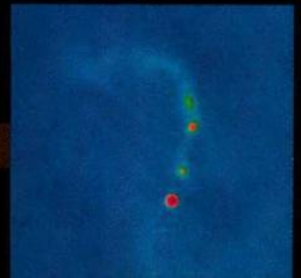


Quasars often show irregular, bumpy shapes in the infrared region of the spectrum.

Radio



A radio-loud quasar (upper curve) is often several thousand times brighter in radio waves than a radio-quiet quasar (lower curve).



Astronomers study all the radiation emitted by quasars — from radio waves to x-rays — to learn what powers these exotic objects.

ejecta model would have about half of the quasars ejected toward us and half away from us, the balance swung in favor of the cosmological model: A quasar's redshift is due to the expansion of the universe and its recessional velocity is proportional to its distance from Earth. Some 4,000 quasars are now known and more are being discovered each day using a variety of techniques.

The Energy Source

The central problem posed by the cosmological model is how quasars generate enough energy to be seen from Earth. The most efficient way to generate energy is through the gravitational pull of a physically small but very massive and dense object, such as a neutron star or black hole. Matter caught in such a gravitational field spirals in toward the neutron star or black hole, forming a rapidly spinning disk, or accretion disk, around the object. As the matter falls inward, about 10 percent of its mass is converted into energy and radiated as light. This type of infall and energy release is known to occur in binary star systems, where the dense companion object has a mass of about 1 to 6 times that of the Sun. However, the typical amount of light generated by a quasar — some 100 billion to 10 trillion times that of the Sun — requires a central black hole of 100 million times the mass of the Sun. Alternatively, some 100 million neutron stars could be the source, but this seems much less probable.

Knowing a way to generate this much energy solves only part of the problem of understanding quasars. We must also show that our model can produce the kind of energy we observe. A black hole and surrounding accretion disk are certainly small and powerful enough to explain quasars' observed sizes and brightnesses, but what else do we know about them?

Quasars emit roughly equal amounts of energy across the electromagnetic spectrum, from infrared to x-ray and possibly gamma-ray frequencies, and roughly 10 percent also emit strong radio radiation. The multi-frequency nature of this emission has long hampered quasar studies. Stars, which emit most of their energy in optical light, have been fully studied and characterized using optical observations alone. In

contrast, quasars emit a wide range of radiation, and we need to observe at all frequencies to completely define their energy distributions — the way their energy is distributed across the spectrum. This requires the use of several different telescopes (infrared, optical, ultraviolet, and x-ray) and observing techniques. Because quasars vary significantly on timescales of a few years, all these data must be collected within about a month to ensure that variability does not affect the results.

Although different quasars exhibit different energy distributions, there appears to be an underlying simplicity to the apparent phenomena. Over the past five years or so, we've learned from multi-frequency observations that the energy distributions can be characterized in terms of a number of different components that dominate the emission in different frequency bands and whose relative strengths change from quasar to quasar. By studying the range of shapes and strengths of each component in comparison with what we expect, we can test our models of how the energy is generated.

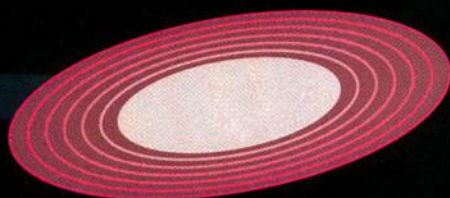
An obvious place to start is with radio emission because we already know that there are two classes of quasar: radio-loud and radio-quiet. Surprisingly, the energy distributions of the two classes are very similar in the infrared, optical, and ultraviolet regions of the spectrum. The major differences between the two classes are in the radio region and in x-rays, where radio-loud quasars tend to be brighter.

Radio emission generally comes from nonthermal sources. The Sun and other stars, as well as the coals in your BBQ grill, are examples of thermal emission — they radiate by virtue of the temperature of the emitting material. Nonthermal emission, on the other hand, is due to a different mechanism. Astronomers think the most likely mechanism for quasars' radio emission is synchrotron radiation created as electrons spiral around magnetic field lines. This radio emission apparently originates in the center of the quasar, close to the black hole. It is not reprocessed — absorbed, scattered, or re-emitted energy from the black hole or accretion disk — but rather a separate, primary energy source.

Recent observations at millimeter wavelengths, which span the gap between the radio and infrared, show that the radio and far-infrared emission in most

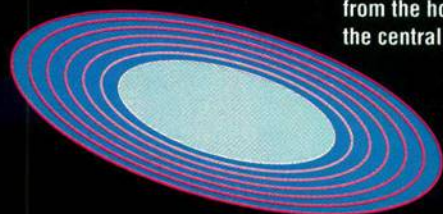
PHYSICAL PROCESSES

X-ray



Many of the x-rays we see originate in the central source but then reflect off gas in the surrounding accretion disk.

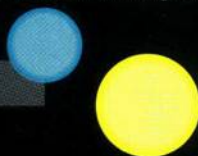
Ultraviolet



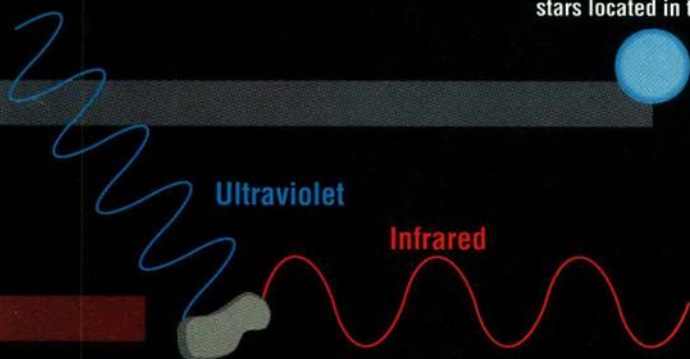
Most ultraviolet radiation is thermal emission from the hot accretion disk surrounding the central black hole.

Optical

Much of the optical radiation in quasars comes from ordinary stars located in the host galaxy.

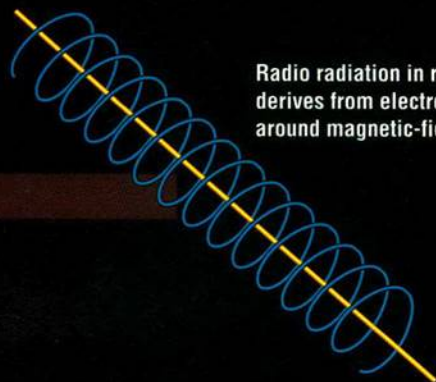


Infrared



Infrared radiation emanates from dust in the host galaxy heated by high-energy radiation from the central source.

Radio



Radio radiation in radio-loud quasars derives from electrons spiraling around magnetic-field lines.

Theoretical models of the physical processes in quasars can account for the radiation we observe.

quasars arise from different mechanisms. Only in the subset of radio-loud quasars that have no extended radio emission (called core-dominated), does the same emission mechanism dominate both regions. This interpretation is consistent with the popular unified scheme for radio sources in which core-dominated quasars are believed to have extended radio emission that points in our direction and appears brighter as a result of its rapid motion toward us relative to the rest of the quasar. The infrared part of the nonthermal emission would be boosted similarly and thus dominate any other components that might contribute in this energy range. If this is true, the main infrared emission mechanism in core-dominated, radio-loud quasars is different from that of other quasars despite its similarity in brightness relative to the optical and ultraviolet emission.

Infrared Emission

If the infrared light in core-dominated, radio-loud quasars is dominated by nonthermal synchrotron emission, what causes the roughly equal amount of infrared light in other quasars? The infrared energy distributions frequently have a bumpy appearance rather than the smooth, straight shape expected for synchrotron emission. Because the energy distribution of thermal emission peaks at a frequency that corresponds to the temperature of the emitting material, an obvious way to get a bumpy distribution is from material emitting at a number of different temperatures. For temperatures corresponding to infrared emission, dust is the most likely candidate material. Dust is bound to be present in the host galaxy and is very likely to be heated by the strong central source. It absorbs this energy, warms up, and then re-emits the energy thermally. This is a form of reprocessed energy. A small amount of thermal emission from dust at several different temperatures combined with nonthermal emission can explain the bumpy shapes we observe.

However, new millimeter observations have raised the question of whether a nonthermal component contributes at all. Instead, perhaps all the infrared emission from quasars is thermal emission from dust. This pure dust model would explain the bumpy shape in the near-infrared as well as the sharp decrease in the energy distribution at wavelengths

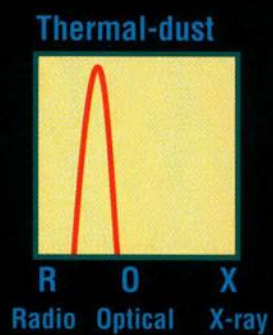
longer than about 100 microns shown by the new observations. A pure dust model would also explain the characteristic dip in the emission as you go from infrared to optical wavelengths (see the diagram on page 36). Dust is destroyed by sublimation at temperatures higher than about 2000 kelvins so there would be no dust to radiate at higher temperatures and give rise to optical light, which is presumably generated by a different process. This maximum temperature also predicts the position of the dip, which always occurs close to 1 micron.

Unfortunately, life is not as simple as this. There are also problems with a pure dust model for the infrared emission. Huge amounts of warm dust would be needed to generate all the energy seen in the infrared. Either the galactic disk must be warped so that large amounts of dust can be heated by the central source or else an additional dust component, such as a torus surrounding the central energy source, must be present. Although evidence for such a torus exists for a few Seyfert 1 galaxies, objects similar to quasars but with lower luminosities, none has been seen in quasars. Another problem with a pure dust model is that the infrared spectra of quasars do not show absorption features due to silicate grains, features that are observed in normal galaxies when dust is present. In order for the model to work then, the dust must have a very different composition from that normally found.

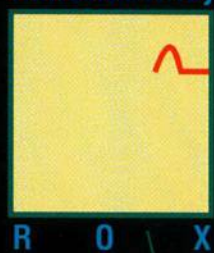
Another problem with the pure dust model is the observed correlation between the near-infrared and x-ray light emitted by quasars. In x-ray bright quasars, at least, this correlation is much stronger than that between the x-ray and emission at any other wavelength. Such a strong correlation implies that the same or related emission mechanisms dominate in the two spectral regions, which is impossible for pure dust emission. One obvious possibility for the source is nonthermal synchrotron emission similar to that in core-dominated, radio-loud quasars.

A Bump in the Light

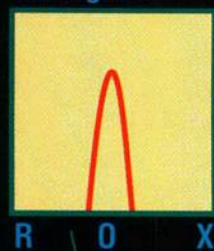
The best evidence that a black hole is the central energy source of a quasar comes from the optical and ultraviolet parts of the spectrum, where quasars put out the greatest fraction of their energy. The curving shape and relative uniformity of this part of the



Reflected X-rays

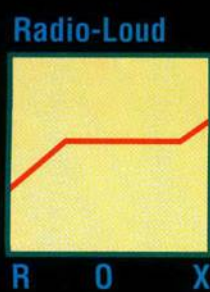
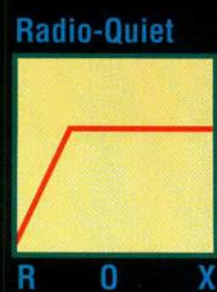


Starlight

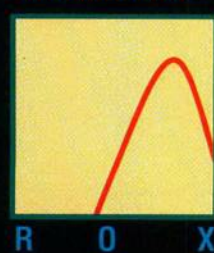


Galaxy

Synchrotron



Thermal-disk



The total output of a quasar is the sum of direct radiation from the central black hole, its accretion disk, and synchrotron radiation and re-emitted radiation from the surrounding dust, gas, and stars.

energy distribution compared with the irregular shape in the infrared led to the name "blue bump." The blue bump peaks somewhere in the extreme ultraviolet region and probably extends into the soft x-ray region around 40 angstroms. This curving, peaky shape suggests thermal emission, but the emission covers a wide range of frequencies and so must come from gas with a range of temperatures. This is very similar to that expected from an accretion disk surrounding a black hole. However, an accretion disk model cannot fully match the optical/ultraviolet distribution of a quasar unless it is combined with a nonthermal component. In this case a good, qualitative, match is obtained, though there are some discrepancies between the detailed predictions of current accretion disk models and observations.

An accretion disk also seems to be the best way to explain the x-ray emission in radio-quiet quasars. In this case, however, the accretion disk reprocesses energy from another primary energy source. Recent observations with the Japanese x-ray satellite Ginga show a strong emission line at 6.4 keV from iron and a broad bump at energies greater than about 10 keV. These features can be explained very nicely if x-rays emitted by a central source reflect off warm (about 10,000 kelvins), optically thick gas located in an accretion disk.

The energy absorbed in this reflection process heats the gas in the accretion disk, which then re-emits thermally in the extreme ultraviolet. This probably plays a role in the blue bump component because the physical conditions are similar. Thus the same accretion disk could be responsible for the blue bump, the soft x-ray excess, and the features in the x-ray emission spectrum. This model not only explains all the current x-ray data for radio-quiet quasars, but also ties in with the emission in the optical and ultraviolet regions. A major remaining question is what generates the original x-ray emission. Two possibilities are non-thermal synchrotron emission and electron/positron pair production, both of which could occur in a region close to and surrounding the black hole.

Putting It All Together

Can we paint a picture of a quasar based on our current knowledge? Although the details still have to be ironed out, the simplified schematic diagram at left shows the likely ingredients and their contributions to the overall continuum emission of a quasar. These ingredients include as primary sources: thermal emission from an accretion disk surrounding a black hole that is heated both by the inward motion of the gas and perhaps by x-rays; non-thermal, synchrotron emission from a source in the core close to the black hole; and x-rays also from a source in the core close to the black hole. The significant sources of reprocessed energy are: reflected x-rays from the inner regions of the accretion disk and thermal emission from warm and cool dust present in the host galaxy and heated by energy from the central regions. Starlight from the stars in the host galaxy also contributes.

Qualitatively, this picture can explain all the data on quasar energy distributions now available to us. As more and better data become available over the next few years, we should be able to quantify the relative contributions and draw more detailed pictures of quasars themselves. In particular, observations of the soft x-ray, extreme ultraviolet, and ultraviolet regions from the ROSAT x-ray satellite and the Hubble Space Telescope already allow a more complete and detailed study of the blue bump. New infrared imaging instruments promise a vast increase in the amount of spectral data in that energy region with which to study the contribution of dust. New and more sensitive millimeter telescopes will also contribute here.

And this only touches on current capabilities. There are many new ground- and space-based facilities planned for the next decade that will help our study of the whole energy distribution. Given the progress over the past few years and the promise of the next few, this is certainly an exciting time in the field of quasar research. □

BURIED AT THE HEART of a quasar is a supermassive black hole that powers all its varied emissions.

Belinda J. Wilkes is an astrophysicist at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts.



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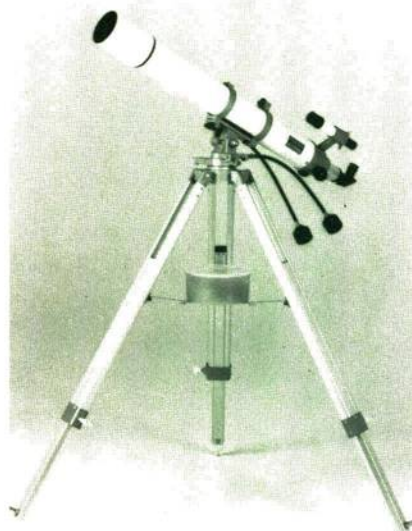
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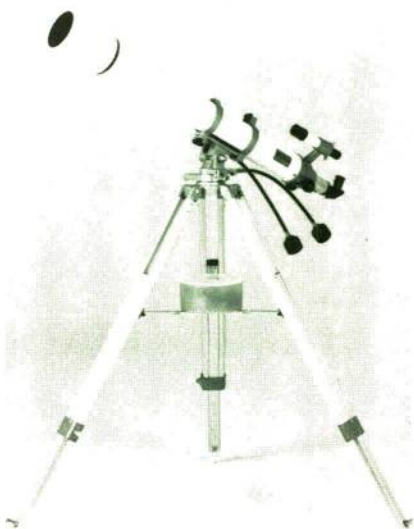
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ANYONE FOR A 94-INCH TELESCOPE?

HUBBLE
REPORT

Five talented amateur astronomers prepare to observe using the Hubble Space Telescope.

by Shireen Gonzaga

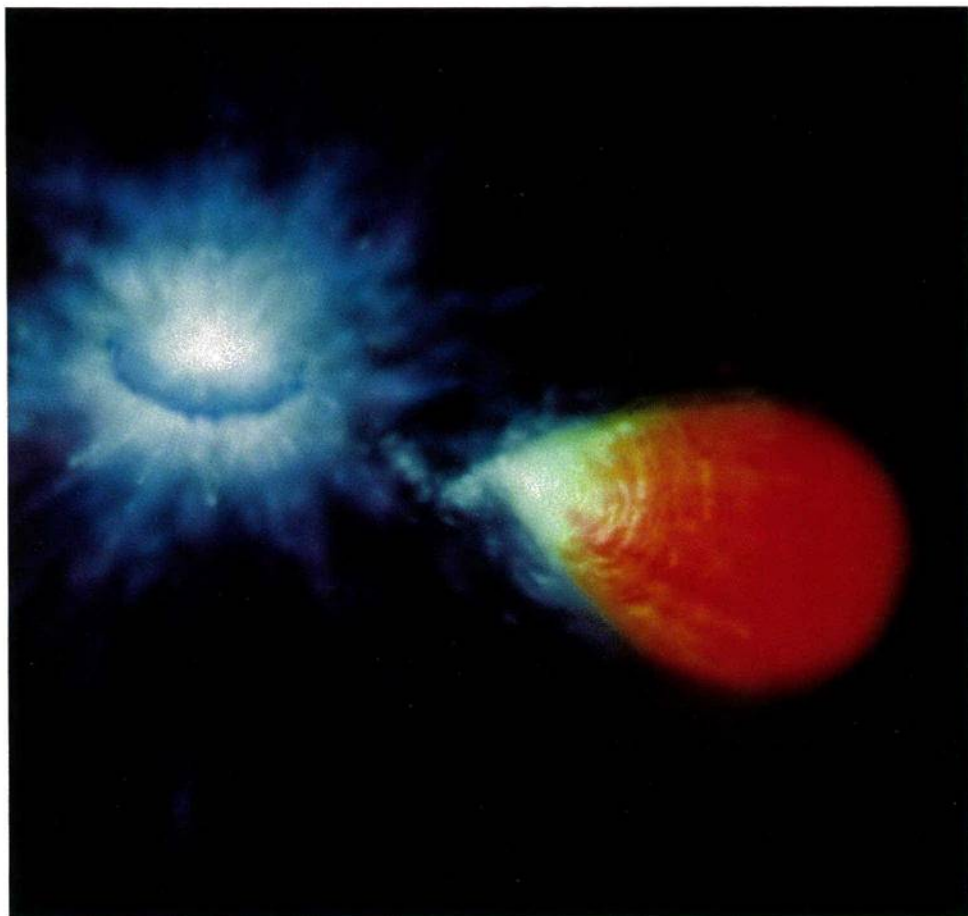
"Amateur astronomers are always standing around with their telescopes, talking about what they would do if only they had a bigger scope, or a different kind of scope," says Berkeley, California amateur John Hewitt. In the near future Hewitt will get the chance to use a bigger telescope — the Hubble Space Telescope. Along with Pete Kandefer, Ana Larson, Jim Secosky, and Ray Sterner, Hewitt hit the jackpot in July 1989 when he survived a vigorous selection process and was given observing time on HST.

The five amateurs will tackle a group of fascinating questions. Is a mysterious intergalactic arc caused by a gravitational lens or is it a star-forming region? Do extra-solar planets exist? Are there swarms of icy comet-like objects enshrouding other stars? What's so peculiar about a star in the Big Dipper? And does it snow on Io? The chance to work with one of the most sophisticated satellites ever built, use state-of-the-art data reduction techniques, followed by publication of results in science journals is ordinarily the domain of professional astronomers. Then why turn over this observing time to amateur astronomers?

In 1986 Riccardo Giacconi, director of the Space Telescope Science Institute (STScI), announced the opportunity for amateur astronomer participation in the HST mission. This program is the first of its kind by any orbiting observatory. "Amateur astronomers are historically not only the creators of knowledge in astronomy, but also the best plugged-in to the general public," says Giacconi.

Space Telescope, Here We Come!

In 1986 a call for observing proposals was announced by the Amateur Astronomer Working Group (AAWG), a group of eight amateur astronomy associations, headed by Stephen Edberg. Two hundred



NEW VISTAS OF THE COSMOS await discovery by five talented amateur astronomers who will use the Hubble Space Telescope for research. Illustration by Dana Berry.

ideas, many with multiple authors, rolled in. After an initial review, 10 proposals were sent to Giacconi, STScI amateur astronomer science manager Eric Chaisson, and STScI deputy director Peter Stockman. They picked the five finalists. Hewitt, Kandefer, Larson, Secosky, and Sterner were invited by Chaisson to STScI in October 1989 to prepare for their upcoming observations.

There, the amateurs underwent the same rigorous preparations that professionals had done: consulting instrument scientists and other telescope experts; de-

ciding on the best instruments, filters, and observing strategies to yield the maximum scientific information; and translating their observing plans into detailed telescope user commands that would eventually be transformed into spacecraft commands. The seventeen hours of spacecraft time unoccluded by Earth shared between them was put to use in the most efficient way possible (their allocation is a small yet significant amount of time compared to about 2,000 hours awarded to professionals). With all of the prep work behind them, the amateurs then awaited their turn on the telescope.

But on June 27, 1990, NASA stunned the astronomical community by announcing that Hubble's 2.4-meter primary mirror was flawed — a textbook case of spherical aberration. The initial disappointment gave way to optimism as the telescope began relaying images of unprecedented resolution, despite

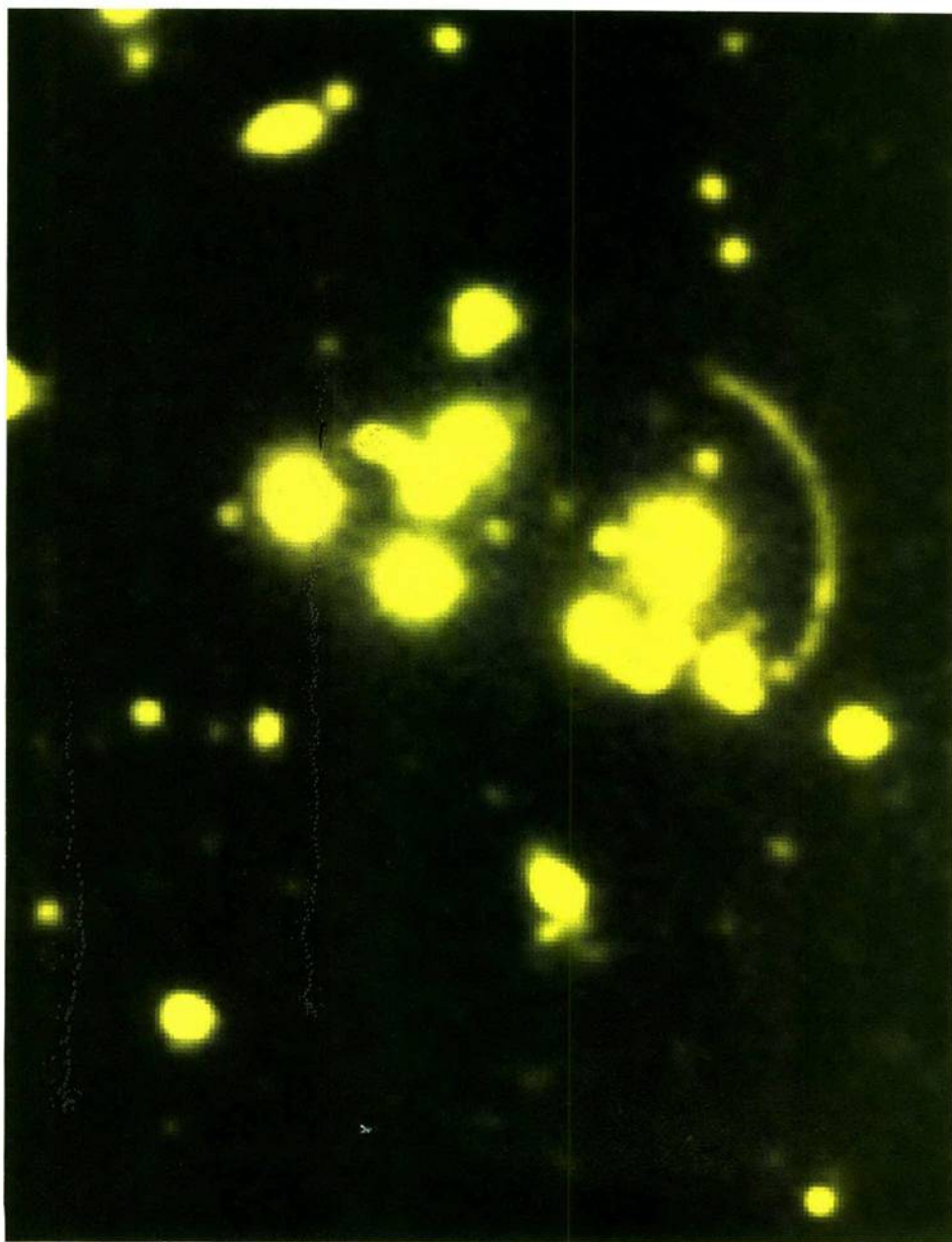
its flaw. Yet the faintest low-contrast objects were rendered unreachable by the mist of the distorted light. For the best results, the world will have to wait until a space shuttle mission in the mid-1990s restores the telescope to its original specifications. In late 1990 it was clear that most observing programs would have to be modified, and some withdrawn. The five amateur programs were no exception. Out of the five, four programs remain feasible with some modifications to observing strategy.

Gravitational Lens vs. Galaxy Collision

Ray Sterner's intergalactic adventures began when he suggested to a disbelieving friend that spiral structure seen in some galaxies could be due to a near collision with another galaxy. To prove it possible, Sterner, a mathematician at the Applied Physics Laboratory in Maryland, created computer models of collision scenarios. One of the models was an off-center hit-and-run: one galaxy slamming into another at approximately two thirds the way from its center to its edge. The result was a curved-in sheet of stars extending out of the disrupted galaxy, with a section of the sheet viewed edgewise resembling an arc.

In 1987, not long after he generated these models, a photograph of a luminous arc in the galaxy cluster CL 2244-02 caught his eye. Some astronomers believe this arc is caused by an effect known as gravitational lensing. The arc may be an illusion, created by immense gravitational forces of a massive galaxy cluster lying in front of a distant object and distorting the distant object's light. This gravitational lens hypothesis is a natural conclusion to draw, given the nearly circular shape of the arc and its geometrical relationship to the galaxy cluster. Yet it also bore a striking resemblance to Sterner's off-center galaxy collision model. He decided to investigate further.

The arc, Sterner learned, had a bluish color, perhaps hinting at the presence of hot, young stars. Galaxy collisions are believed to trigger the formation of many hot massive stars with lifetimes on the order of only tens of millions of years. Diving back into his computer modeling, Sterner tried constraining the arc to form on the



THE MYSTERIOUS GALACTIC ARC in galaxy cluster CL 2242-02 will be investigated by Ray Sterner of Woodbine, Maryland. National Optical Astronomy Observatories photo.

same timescale of the lives of massive stars. But it was impossible. The best he could do was create an arc over a period of a few hundred million years. There had to be some mechanism at work busily rejuvenating the supply of stars in the arc.

Sterner was able to construct a possible scenario for the formation of CL 2244-02's arc. An off-center collision disrupted a normal spiral galaxy, creating a curved sheet of stars extending out of the spiral, with a slightly curled-up part of it that when viewed edge-on, resembled an arc due to the higher concentration of stars visible along the line of sight. The second galaxy, theorized Sterner, could be a nearby galaxy that has been found to emit radio waves, perhaps due to a black hole devouring the dust and gas swept up by the collision.

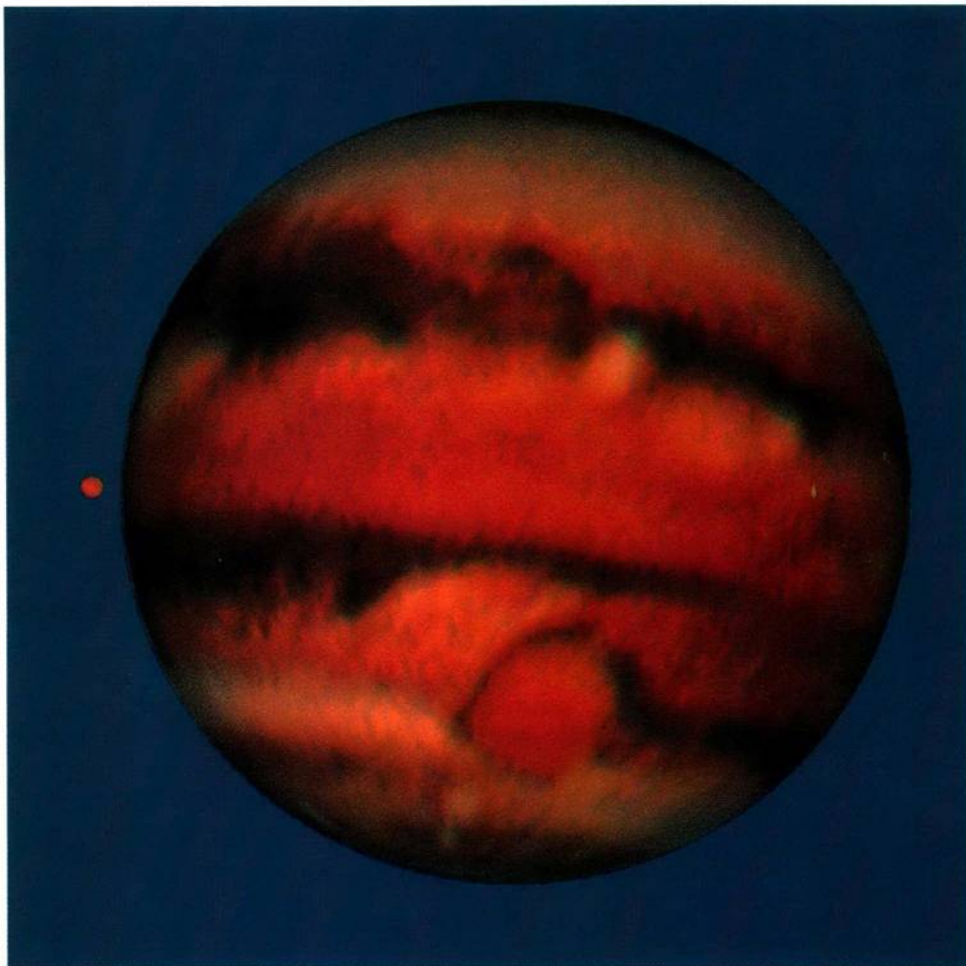
The collision triggered a vigorous burst of star formation, populating the arc with hot massive stars. These heavyweights emitted a powerful stream of charged particles known as stellar winds, and some stars were so massive that they ended their lives in violent supernova explosions that emitted powerful shockwaves. The stellar winds and supernovae shockwaves created a sort of "intergalactic dam" — a barrier against which hot gases permeating the medium of the galaxy cluster would pile up. As the gas accumulated, it clumped together, forming a new generation of massive stars. If Sterner is right about CL 2244-02, he will have discovered an extraordinary event — the formation of stars outside a galaxy.

An Ionian Mystery

Since 1964, scientists have noticed a curious phenomenon on Io, the innermost of Jupiter's Galilean moons. As it emerges out of Jupiter's shadow following an eclipse, Io appears a little brighter than usual. This odd effect, however, fades away within 10 or 15 minutes of Io's reappearance. To add to the mystery, these sightings are sporadic, observed during some post-eclipse events, yet not during others. The brief visits by Voyagers 1 and 2 to the Jovian system only added to the puzzle, detecting a brief, small brightening in the south polar region that was not detected by Earth-based observations. Yet whenever the post-eclipsed Io is observed from the ground, all observers obtain the same results for the same events, whether a brightening is seen or not, indicating that there may in fact be something happening on Io.

Earth's atmosphere continually teases terrestrial observers of these events, tainting sensitive photometric observations of the post-eclipsed Io with scattered light from its brilliant parent Jupiter. Jim Secosky, a

science teacher at Bloomfield Central Junior-Senior High School in New York, will use HST's unique advantages to find out what is really going on: is the Earth's atmosphere playing tricks on us, or Io itself? Io could well be the culprit. "It has been suggested in the literature," explained Secosky, "that as Io goes into the shadow of Jupiter, it gets colder. And when it gets colder, snow or frost forms. Then, when Io comes out of the eclipse, it is much brighter because of the snow or frost. After about 10 or 15 minutes, the



IO'S POST-ECLIPSE BRIGHTENING is the focus of a project by Jim Secosky of Manchester, New York. Illustration by Dana Berry.

light from the Sun warms Io, melts the snow or frost and Io decreases to its normal brightness."

Using HST's Planetary Camera, Secosky will watch Io as it slips out of Jupiter's shadow. He will use a technique that is fast becoming popular among many HST observers: image deconvolution. This method of image processing attempts to clean images with spherical aberration by removing the obscuring effects of the halo around the image. It can never fully compensate for the effects of the aberration, but does allow for some reconstruction of bright high-contrast objects. To deconvolve an image of Io, Secosky will

also observe a star which will help him to restore the images. He will take a series of photographs using two filters. By looking at the various features in each filter and comparing the image of Io with the star's image, Secosky will be able to subtract the image flaws.

Which regions of the Ionian surface outshine others? Will areas covered with sulfur dioxide snow stand out? What will the observation tell us about the Ionian weather system? Perhaps Jim Secosky will

DETECTING A SHELL OF COMETS around another star can be accomplished by observing a nova explosion, hopes John Hewitt. Illustration by Adolf Schaller.

have the final say in this mystery of the solar system.

A Lazy Way To Find Comets

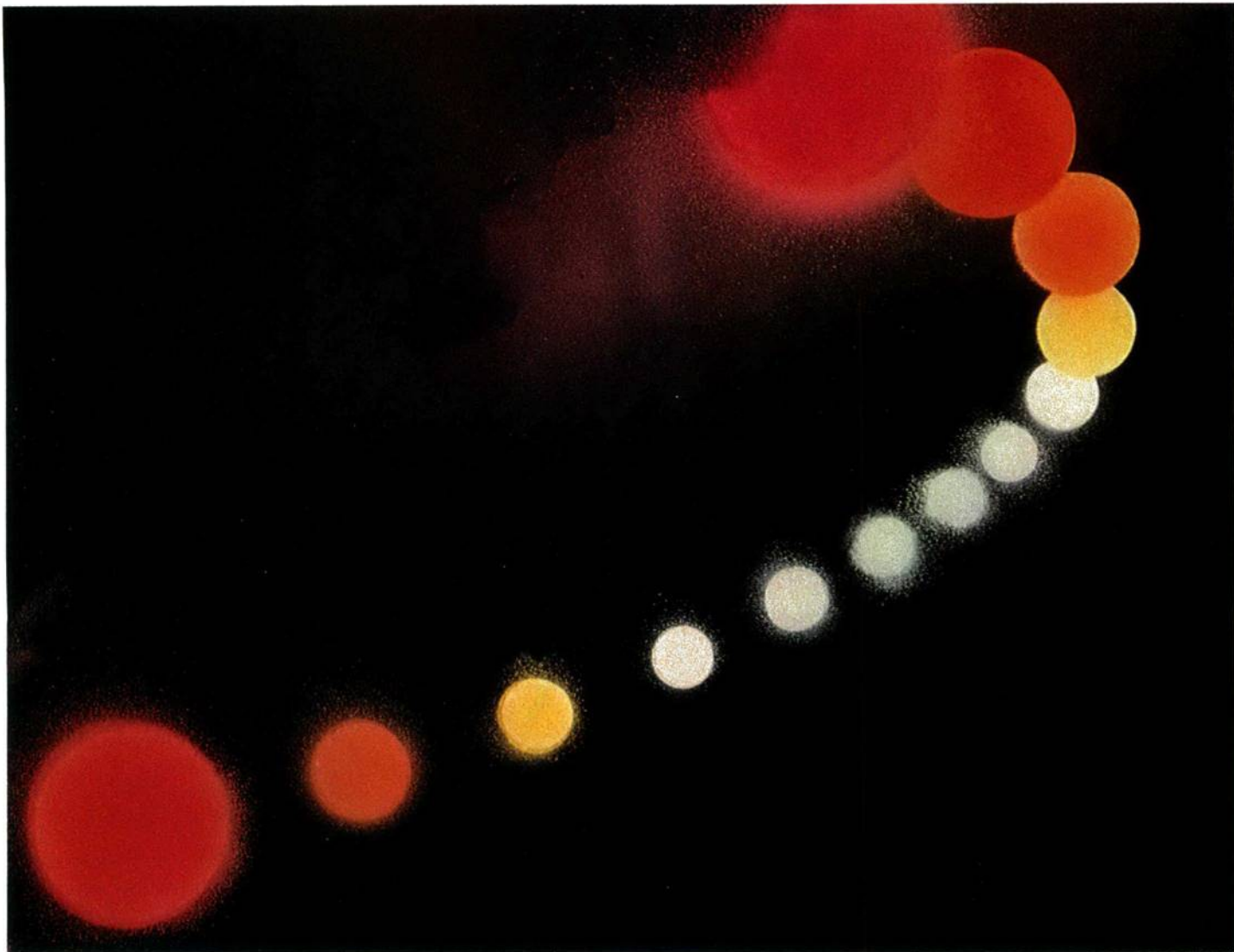
John Hewitt will search for a swarm of comets around another star. Comets, believed to be ancient relics of the primordial solar system, are thought to originate from the Oort cloud, a collection of would-be comets that enshroud the Sun and planets. Yet detecting the Oort cloud is exceedingly difficult even with state-of-the-art astronomical detectors of today. These primordial chunks of dust and ice skulk the very fringes of the solar system, 30,000 to 100,000 AU away, basking in the feeble light of the faraway Sun that appears as bright to these comets as Sirius does to us.

If we can't see our own Oort cloud, how do we expect to detect one belonging to another star? Hewitt's strategy: get some help from a nova. Novae, close binary star systems that erupt in thermonuclear explosions caused by mass transfer between the stars, are characterized by a sudden sharp increase in brightness. As the brilliant light pulse travels outward, it interacts with objects in its path leaving telltale spectral signatures of elements and molecules it brushed past. Hewitt's hope, therefore, is to use the nova's bright light flash to illuminate the Oort cloud surrounding the nova.

Oort cloud objects are believed to contain simple molecules such as carbon monoxide, carbon dioxide, methane, ammonia, carbon disulfide, and, most of all, water, locked in a seemingly eternal deep freeze. Occasionally, an Oort cloud object is nudged out of its orbit, perhaps by a passing star, toward the inner solar system. As it approaches the Sun, it warms up, particles sublime into gases, and dust and gas are swept back by solar radiation pressure and the solar wind. This produces the comet's trademark tail.

If a nova had an Oort cloud, the powerful light pulse would agitate its Oort cloud icebergs much as a comet in the inner solar system is affected by the Sun's radiation. A nova suitable for Hewitt's studies will have to erupt in our Galaxy during Hewitt's HST observing time — a one-year period that began in July 1991. If a bright nova appears with no bright foreground objects to contaminate the data, Hewitt will use HST's Wide Field Camera to image the vicinity of the nova at in-





tervals of perhaps 20 days up to 120 days after maximum brightness. This would allow the light pulse, racing outward at 173 astronomical units per day, to reach the regions of the nova's system that are most likely to contain Oort cloud features, unveiling the structures and dimensions of the cloud.

Hewitt will look for the signature of water in the ultraviolet, possible only above Earth's obscuring atmosphere. To be more accurate, he will look for the dissociation product of water called hydroxyl, a hydrogen-oxygen molecule stripped of its second hydrogen atom that once made it a water molecule. The dissociation of water by the nova's light pulse is visible as ultraviolet spectral emission from the Oort cloud objects.

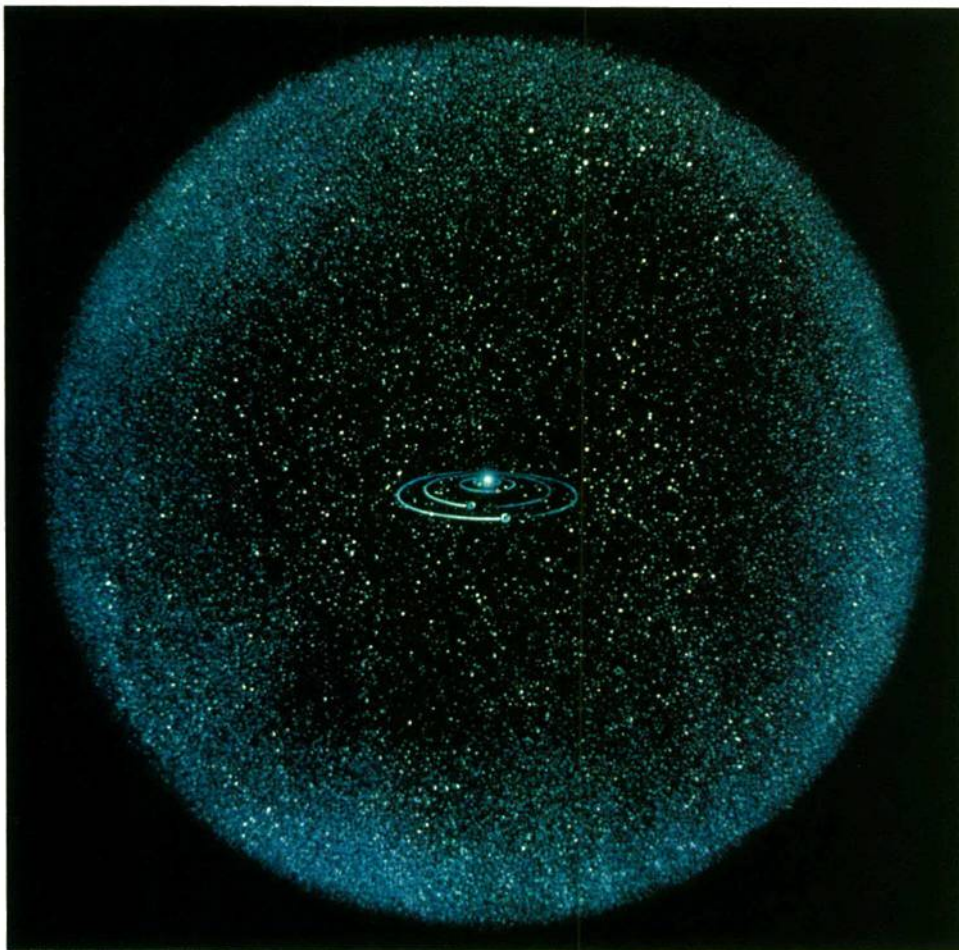
Novae are classified in HST jargon as targets of opportunity, a fancy name for celestial surprises. Because of the uncertain nature of his observing program, many of the observing parameters required for his program cannot be determined until a nova actually goes off. If Hewitt could beat the odds and in fact detect a nova's Oort cloud, it would make for a priceless contribution to understanding stellar formation and the interaction of stars with the interstellar medium. And he would certainly give the old game of comet-hunting a new twist.

AN ODD VARIABLE STAR will be studied by Peter Kandefer of New Hartford, Connecticut. Artwork by Ernest Norcia.

A Peculiar Star in the Big Dipper

Stargazers of the Northern Hemisphere hold deep affection for the Big Dipper, one of the best-known star patterns to grace the night sky. The third star on the handle, joining the cup of the dipper, will never quite seem the same again to Peter Kandefer. An amateur astronomer from New Hartford, Connecticut, Kandefer will use HST to investigate this star's peculiar spectrum.

Alioth, otherwise known as HD 112185, is a variable star with a very well-defined period, its brightness changing by 0.03 magnitude every 5.09 days. It is part of a distinct class of A-type stars that have peculiar features in their spectra. Some of them fluctuate in brightness, and display unusually strong spectral lines of silicon, strontium, and chromium, as well as high surface abundances of rare earth elements like europium. Some spectral lines are periodically observed to weaken, while others gain strength. The Zeeman effect, where a spectral line is visibly split into several components, betrays the presence of strong magnetic fields on these stars. Changes in the stars' magnetic fields appear to be linked to the spectral line intensity variations. It's no wonder astronomers refer to these objects as peculiar stars.



PLANETS ORBITING OTHER STARS was to have been the subject of a search by Ana M. Larson of Victoria, British Columbia. Illustration by Tom Miller.

Why do these stars behave so strangely? Astronomers believe that their observed characteristics can be attributed to the congregation of various elements in different locations on the star's surface. The changing lines of the spectral features will allow Kandeler to measure the star's varying magnetic field strength and thereby reconstruct the physical geometry of the star's magnetic field orientation. The result of this complicated analysis will be of great value to research into understanding the evolution and structure of stars.

Catching the Birth of A Planet

The search for extrasolar planets is perhaps one of the most exciting and compelling items on the list of things-to-do in the astronomical community. There is indirect evidence for planets around other stars, for example, the wobbling motion of stars due to unseen companions detected by astrometric observations, and the spectacular image of Beta Pictoris with its ring of circumstellar matter.

Narrowing the search for extrasolar planets among the myriad of stars can be attempted by beginning with educated guesses of where to look, how to look, and even when to look — a set of requirements that differ from observer to observer. Ana Larson, a student at the University of Victoria in Canada, had

planned to be the first to bring HST into the hunt — hoping to look for planets forming around T-Tauri stars — young stars in hot cocoons of gas — by directly imaging them in near-infrared wavelengths of radiation.

Larson calculated that given certain conditions, it was theoretically possible for such a protoplanet to be visible using HST. At the distance of the Taurus-Auriga complex, 160 parsecs, a protoplanet of 5 to 10 Jovian masses would radiate enough in the near-infrared for a brief interval of time to be detectable by HST's cameras, providing it were at least 10 astronomical units from the star (the approximate distance of Saturn from the Sun). Larson had planned to look at five candidate stars in the Taurus region of the sky, stars that she believes are the best bet for planetary formation. Unfortunately, any smidgen of light that would betray the presence of a protoplanet next to a T-Tauri star will be lost in the halo of starlight caused by the spherical aberration. So Larson will have to wait until the mirror is fixed.

Sometime this year, Kandeler, Secosky, Sterner, and hopefully Hewitt will be notified regarding their turn on the telescope. Once the data are obtained, the most challenging part of their projects will begin. They will be faced with the time-consuming task of reducing and analyzing their data, and of course sharing the information with a curious audience of their peers, professional astronomers, and the public. While the first batch of HST amateur astronomers are busy with this post-observation phase, another group will be wading through their piles of HST observing manuals and catalogs, putting together yet another cycle of amateur astronomer observing plans. Last year, the AAWG announced a call for proposals for the second cycle of the HST Amateur Astronomer Project. Further information can be obtained from Janet Mattei, Director of the AAVSO, at 25 Birch St., Cambridge, MA 02138. There is tremendous potential for this unique program. Commenting on the valuable contributions by amateurs with their modest observing instruments, and this new opportunity to observe with a telescope like Hubble, Giacconi observed, "They'll have to change their point of view. Instead of trying to do the best they could from what limited resources they have, they'll have to do the best science they can with that new resource." □

Shireen Gonzaga is a technical assistant at the Space Telescope Science Institute in Baltimore, Maryland. Her last article for ASTRONOMY was "The Moon has a Cometlike Sodium Cloud" (October 1991).

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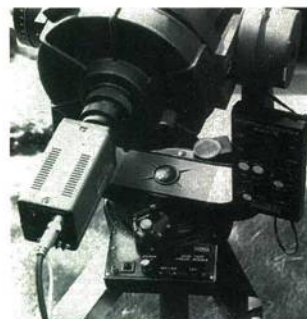
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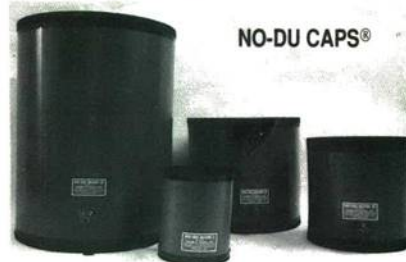
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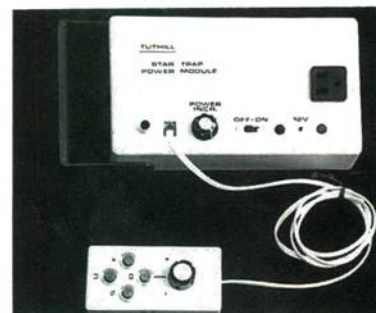


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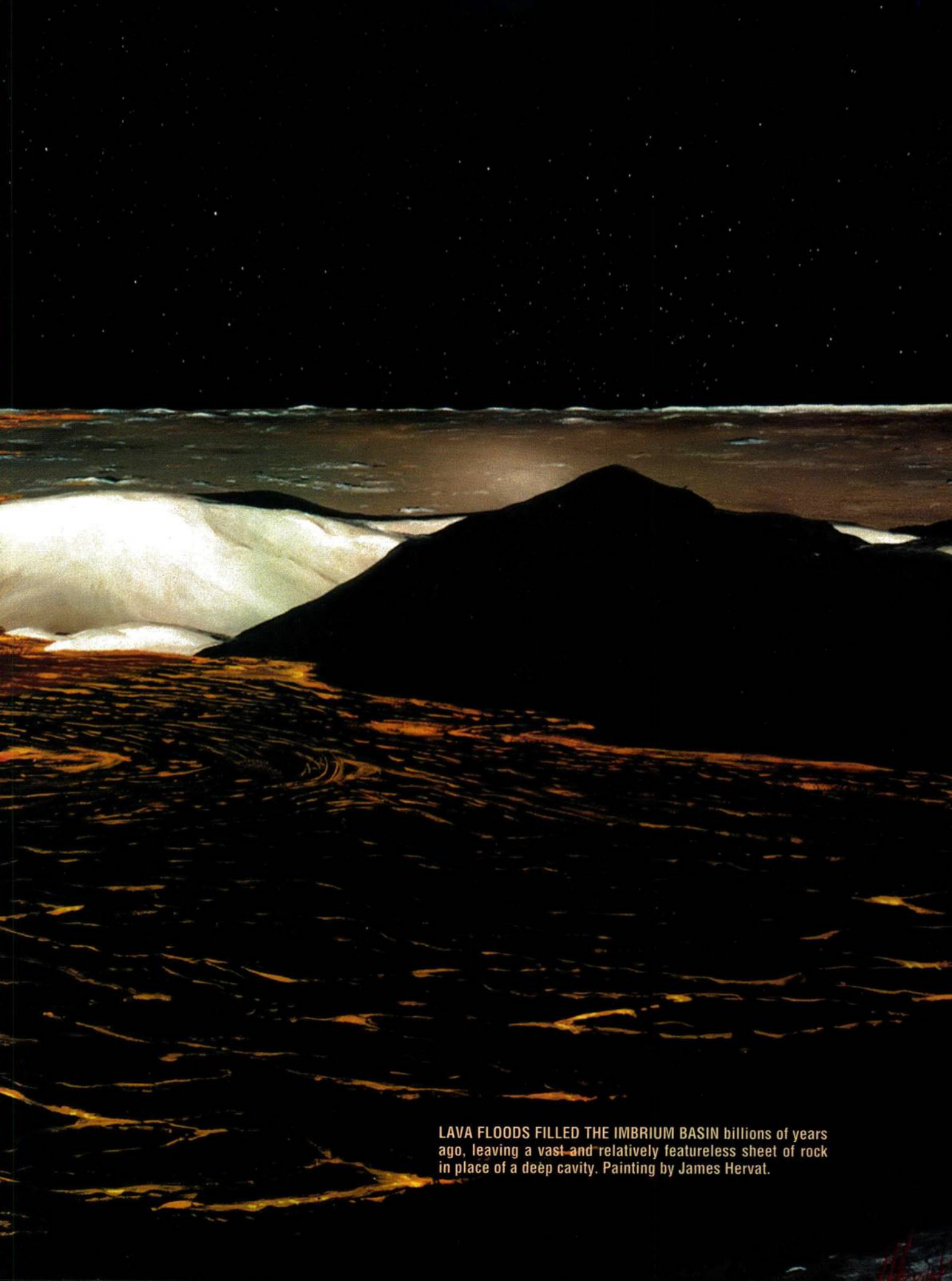
LUNAR GEOLOGY

Mysteries of the Moon

There's an unknown Moon hanging silently, beautifully in our sky. It's the Moon whose mysteries Apollo didn't fully fathom — and it may be the most intriguing Moon of all.

by Damond Benningfield





LAVA FLOODS FILLED THE IMBRIUM BASIN billions of years ago, leaving a vast and relatively featureless sheet of rock in place of a deep cavity. Painting by James Hervat.

Project Apollo was supposed to be the next-to-last chapter of an exciting celestial mystery novel. Earth-bound scientists were supposed to take the 842 pounds of lunar rocks and soil, thousands of sharp photographs, and millions of bits of electronic data and out of them piece together the Moon's origin, its evolution, its structure, and its composition. Just open the boxes, fiddle with the rocks a bit, write up the last chapter, and — *voilà!* — the Moon would be a closed book.

Reality, of course, is seldom so tidy. Data from Apollo and a flotilla of unmanned Moon orbiters, crashers, and landers have yielded many answers, but few of the solutions are as elementary as those in a Sherlock Holmes story.

For example, consider the question of the Moon's origin. Working from Apollo data, planetary scientists now believe that the Moon was born in a violent collision between Earth and a Mars-sized planetoid soon after Earth formed. But this giant impact hypothesis is still little more than a general idea; details are hazy. There is lively debate, for instance, over the exact parentage of the present-day Moon: Did it form from material gouged from the primitive Earth? Or from debris from the rogue planet? Or some combination of the two? For that matter, is our present Moon an only child or the sole survivor of a multiple-moon system?

Or look at the Moon's brutally scarred surface. Billions of years of bombardment by meteorites of all sizes have left a tangled history we understand only partly. Many scientists think the period of violent activity lasted several hundred million years during the Moon's earliest years. But some say the barrage might have taken place during a tight 40-million-year window — perhaps after other moons were pulverized in their own giant collision.

And then there's the issue of lunar water. There isn't any. That is, unless hidden pockets of ice have survived billions of years of harsh conditions at the Moon's poles.

"We have a much more complicated picture of the Moon today than we had in 1974, when a lot of people got out of the field," explains Graham Ryder, a U.K.-born staff scientist at the Lunar and Planetary Institute in Houston. "It's like the Bob Dylan line 'We were so much older then.' We used to know it all."

Today, planetary scientists are quick to acknowledge that they don't know it all. In fact, lunar research is an active and healthy field of study. Researchers continually find new ways to dissect the Apollo samples and to interpret old results. And new

generations of ever-faster supercomputers make it possible to simulate a wide range of conditions throughout the Moon's lifetime. But even with our new tools, new talent, and a libraryful of new ideas, the Moon continues to hold tight to some of its oldest and most cherished secrets.

How to Make a Moon

One of the most intriguing secrets — its solution was a sort of Holy Grail for Apollo — is the Moon's origin. For many years scientists thought the Moon was born in one of three ways: it formed from the same primordial cloud of gas and dust as Earth, or it spun free from the primordial Earth, or it was a stray that wandered too near Earth and was captured by

the larger body's more powerful gravitational pull. But the Apollo samples demonstrated that the correct answer is "none of the above."

"The three classical theories all falter on the chemistry," says Jay Melosh, a planetary scientist at the University of Arizona's Lunar and Planetary Laboratory in Tucson. Melosh notes that the giant-impact hypothesis, first suggested in the mid-1970s but not gaining wide acceptance until a decade later, "does a pretty good first-order job of explaining the chemistry and dynamics of the Moon." For example, it

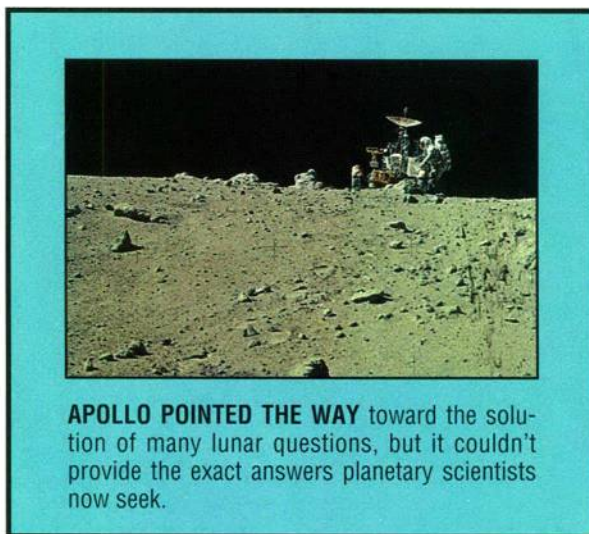
explains why the Moon lacks heavy elements common on Earth.

According to Melosh's model, very soon after Earth formed 4.5 billion years ago, a planet about 1.5 times more massive than Mars (or 15% as massive as Earth) struck the newborn Earth at an oblique angle. The impact vaporized a large part of Earth's crust and upper mantle, spewing it into space like a jet. The blast also accelerated Earth's rotation, spinning the planet up like a child's top.

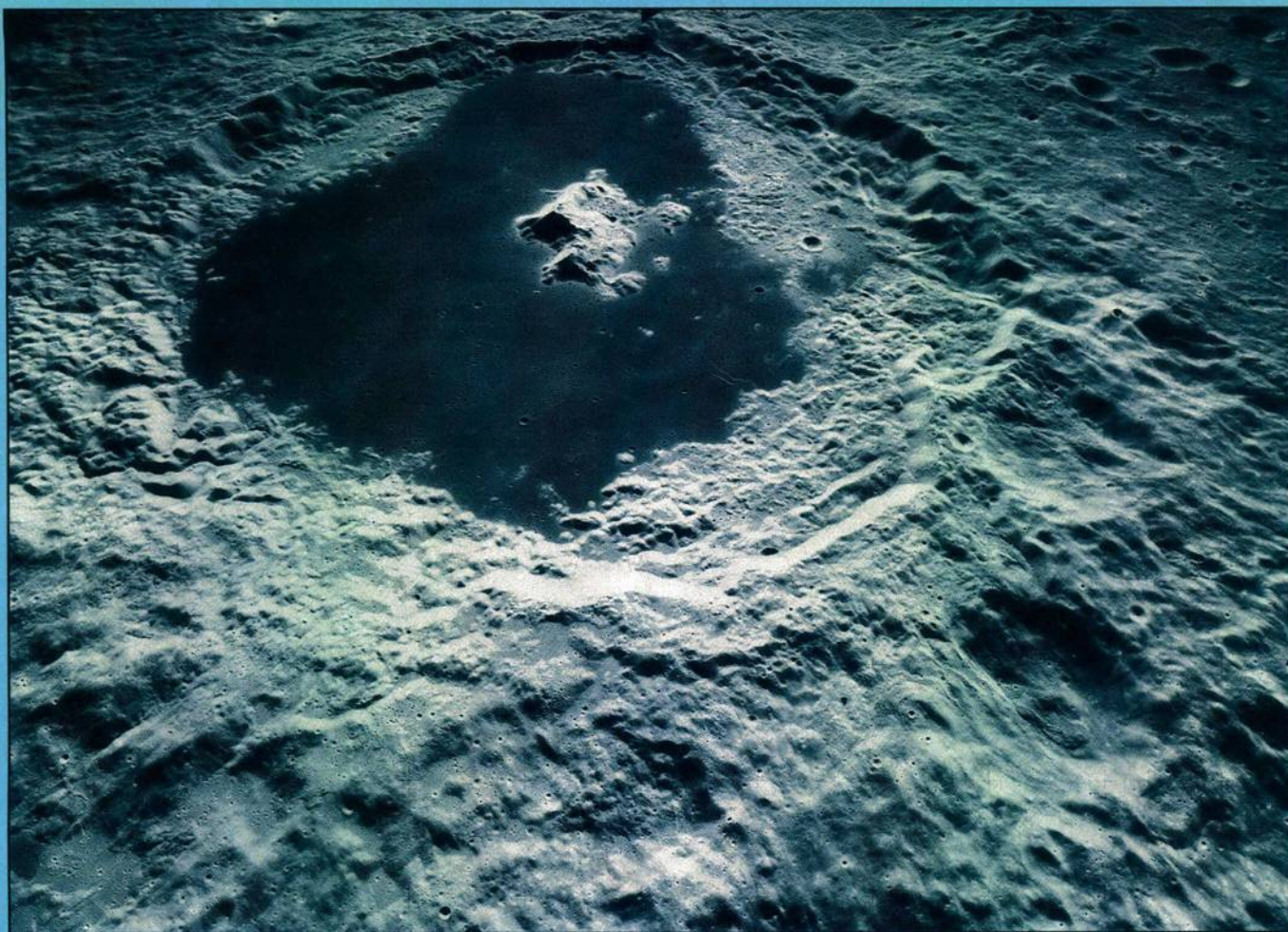
The jet contained mostly light material from Earth's outermost layers. Largely missing were heavy iron and nickel — the main components of Earth's core. The material that squirted into space settled into a hot disk around Earth relatively nearby. The disk quickly cooled and the vapor condensed to form a thick ring of small particles. In perhaps only a thousand years or less, these particles coalesced to form the Moon.

So Far, So Good

Most planetary scientists agree with this broad outline of events, but there are exceptions. Some believe that the vapor disk was created by a series of smaller impacts. But giant-impact proponents counter that such a sequence could not account for Earth's



APOLLO POINTED THE WAY toward the solution of many lunar questions, but it couldn't provide the exact answers planetary scientists now seek.



SHOWPIECE CRATER OF THE LUNAR FARSIDE, Tsiolkowsky invites scrutiny from those who want to probe its structure, study how its rocks relate to the surroundings, and analyze its lava flows. For example, are all the craterlets on its dark floor caused by impacts — or are some of them volcanic?

rapid rotation rate. Multiple impacts would follow a random pattern, and their rotational effects would tend to cancel one another out.

Yet major questions remain unanswered. At the top of the list is the fate of the planet that caused all of this mayhem. One group, led by Melosh, says that as much as half of the impactor was vaporized in the collision and became part of the disk that later formed the Moon. Another group, led by Alastair G. W. Cameron, an astronomer at Harvard-Smithsonian Center for Astrophysics, says that the Melosh scenario "is possible, but it's probably not the way things really happened." Instead, Cameron believes, most of the impactor skipped off the rattled Earth, like a stone skimming over a pond, with its core sinking through the molten soup all the way to Earth's core.

Calculating Chaos in a Computer

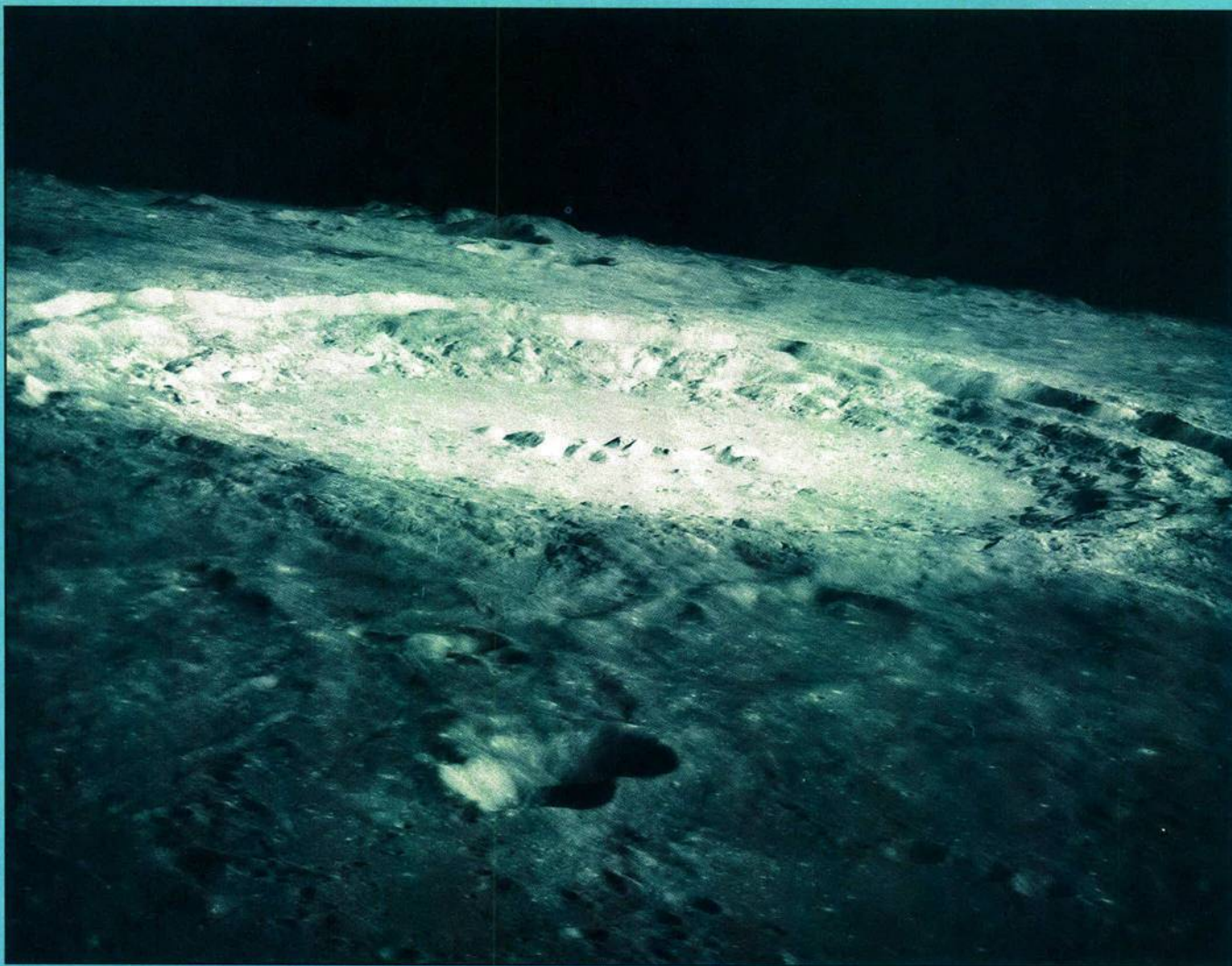
This will be a difficult question to resolve. No one knows the chemical composition of the impactor, but if enough Moon samples turn up elements that can be identified as not occurring on Earth, there's a good chance they came from the object. Yet it may prove impossible to know for sure how much of the

impactor was incorporated into the Moon and how much merged with Earth. Both Melosh and Cameron are using supercomputers to run complex simulations of conditions during and after the impact. These help narrow the range of possibilities, though they are unlikely to provide definitive answers.

So far, the simulations have focused on the impact itself and on the first chaotic minutes after. No one has even tried to model the details of lunar accretion — the process by which tiny lumps of matter merge to form larger lumps and eventually a Moon. Ryder thinks that when someone does model the process, the results will be astounding — the cooling disk will yield several Moons.

"My own gut feeling," he says, "is that Earth had three or four Moons." Ryder bases this on an examination of meteorite bombardment of the lunar surface a few hundred million years after the Moon formed.

Although many researchers argue that the Moon was blasted by meteorites for several hundred million years, Ryder says that Apollo samples indicate there was little meteorite activity from about 4.4 billion years ago — when a primitive solid crust formed atop the molten interior — until 3.9 billion



FAMILIAR TO EVERY TELESCOPE OWNER, Copernicus was to be a target for one of the canceled Apollo missions. Moon scientists think this 810-million-year-old impact could help us probe the layers underlying Mare Imbrium.

years ago, “when all hell broke loose.” Then from 3.87 to 3.83 billion years ago, Ryder believes the Moon underwent a “cataclysmic” bombardment, with meteorites pounding the surface mercilessly. The source of this big-league hailstorm? Earth’s other Moons, which were pulverized in their own giant impacts, Ryder says.

For evidence, he points to a detailed study of the ages of several Apollo samples. Using a new laser dating technique, Ryder and a colleague have evaluated about a half-dozen samples from Apollo 15, which landed on the rim of the Imbrium Basin, a giant impact feature in the Moon’s northern hemisphere. The dating technique compares the ratios of several isotopes (different nuclear forms of a chemical element) inside the sample to determine its age.

The internal clocks of all of the samples were “reset” — something that can be done only when the rocks melt completely — less than 3.9 billion years ago. Ryder says that a leisurely impact rate spread out over a few hundred million years wouldn’t generate enough heat to reset the isotopic clocks. “The idea that you can reset these isotopes

without a cataclysm just isn’t on,” he says. “It’s fairly convincing that there was a cataclysm. If we go back to the Moon, we can figure it out.”

If Not Green Cheese, Then What?

There are many other questions that scientists don’t believe they can answer until astronauts or spacecraft return to the Moon. For example: What is the Moon made of?

Scientists think they have a pretty good general idea of the Moon’s chemical composition, but this is based mainly on detailed study of just nine spots on the Moon’s surface (six Apollo sites and three unmanned Soviet Luna landing sites). Instruments aboard orbiting Apollo service modules added some rough estimates of the composition of other areas, but none of the instruments scanned more than 20% of the lunar surface, and most saw only about 5%. Our picture of the Moon, unfortunately, is painted with a broad brush — and Apollo taught us that the most interesting secrets are revealed in the micro-details.

“We don’t know that much about fine-scale chemical distribution on the Moon,” says John Diet-

rich, curator of the Lunar Curatorial Facility, the Apollo sample repository at NASA's Johnson Space Center in Houston. "We can take a first guess based on what we have. We suspect that the rocks at the poles are similar to those at the equatorial regions, but we just don't know for sure."

All but one of the Apollo missions and all three Soviet Luna sample-return probes visited the lunar maria, the prominent dark "seas" that are vast basins flooded with dense volcanic rock. Only Apollo 16 sampled the highlands regions, the light-colored areas that are mangled collections of mountains, canyons, and craters.

"Most of the Moon, including almost all of the far-side, is highlands and most of our samples are from the maria," says Dietrich.

Just as important, all nine sample sites lie within a relatively small box on the Moon's nearside. "We sampled very few kinds of rocks and it's important to sample others," says William Muehlberger, a University of Texas geology professor and principal investigator for the Apollo 16 and 17 geological explorations.

Another problem is that all the samples came from only the top few feet of the Moon's surface. Some of the rock and soil samples were gouged from greater depths by meteorite impacts, but no one can say for certain which samples came from what depth. Until future explorers penetrate well below the surface or obtain samples that scientists are certain were blasted from a given depth, it will be almost impossible to determine the composition (and structure) of the Moon's subsurface layers.

Waters of the Moon?

Perhaps the most surprising gap in our knowledge of the Moon is the lack of detailed maps of the farside and the polar regions. "We have better coverage of Mars than of the Moon," says Ryder.

Five American Lunar Orbiter spacecraft, sent to scout for good Apollo landing sites, snapped about 2,000 sharp photos of the Moon during the mid-1960s. Astronauts and automated cameras aboard the Apollo missions added thousands more. But the orbits of these vehicles seldom carried them more than 30° north or south of the lunar equator. And because all the Apollo landings were planned for the nearside, the Lunar Orbiters concentrated their observations on the face we see from Earth.

This means nearly all the Moon has been mapped at medium resolution and small areas at high resolution. But missions to other planets have shown that getting sharper pictures means that your understanding changes, even dramatically. For example, one gap in resolution and understanding emerged when the Galileo spacecraft swept past Earth and the Moon in December 1990 en route to Jupiter. Images taken by Galileo multispectral imager confirmed the existence of an ancient farside impact basin to the southwest of Mare Orientale. This basin

has been pounded so heavily since its formation that it is almost impossible to recognize as a basin, but it is about 2,200 kilometers across. The feature was not detected in the available orbital photography. The Lunar Observer project, which would place an advanced scientific spacecraft in lunar orbit by the end of the decade, could fill in most of the blanks in our maps of the Moon.

Lunar Observer also could look for something that most scientists don't believe exists — lunar water. Apollo samples have shown no trace of water, past or present. Yet some researchers believe that pockets of water ice and other frozen volatiles might exist at the lunar poles. They say that comets striking

the Moon's polar regions might have found a few lucky spots inside steep-walled craters such as Peary, Hermite, and Amundsen that receive little or no direct sunlight. Temperatures during the long lunar day can top 250° Fahrenheit, so any exposure to the Sun would vaporize icy deposits.

At the 1987 Lunar and Planetary Science Conference, James Arnold of the University of California at San Diego

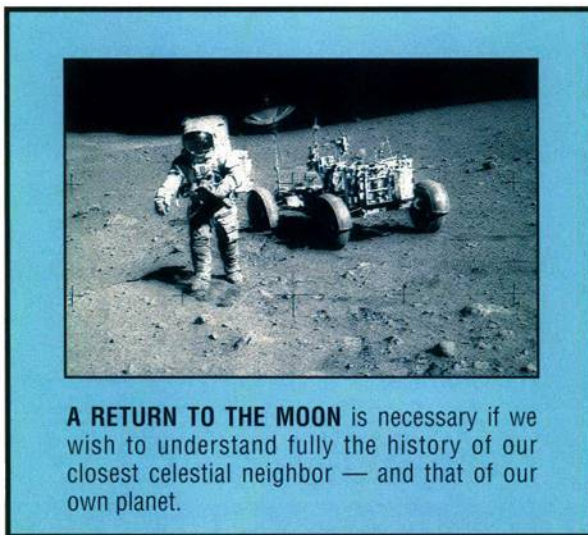
suggested that material from comets might become buried after it strikes the surface. In all, he said, as much as 35,000 square kilometers — about 0.1% of the lunar surface — might provide safe haven for icy deposits. Lunar Observer, which will orbit from pole to pole, should detect water ice or other frozen deposits buried up to a meter beneath the lunar surface using highly sensitive gamma-ray spectrometers.

Toward the Unknown Regions

Lunar science today stands on a firm foundation thanks to Apollo. Some people might want to declare the story over, snap the book shut, and go on with other matters. Yet if we stop here we will be abandoning a small planet full of mysteries right on our own doorstep.

The Moon and its history are an integral part of our own planet's past. Apollo pointed out the next questions to ask of the Moon, but our nearest celestial neighbor is too big, too far away, and too old to serve up its secrets without a lot more digging. □

Damond Benningfield is a science writer based in Austin, Texas. His last article for ASTRONOMY was "Where do Comets Come From?" in the September 1990 issue.



A RETURN TO THE MOON is necessary if we wish to understand fully the history of our closest celestial neighbor — and that of our own planet.

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Galaxies NGC 4631 (left) and NGC 4656/7 (right) in Canes Venatici. 50 minute exposure by Martin Germano using 2415 hypered in a LUMICON Hyper-Kit and an 8" f/5 telescope with a LUMICON 2" Newtonian Easy-Guider. Much detail can be seen in 9th magnitude NGC 4631. Look for nearby 12th magnitude NGC 4627. NGC 4656/7 has an interesting hook; look for the hard-to-see faint extension doubling its length.

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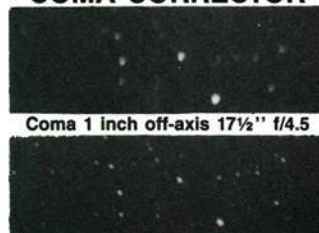
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PREMIER 2080 Model 50SD \$1950

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COMA CORRECTOR



Same field with LUMICON 2" corrector; smaller, more numerous stars.

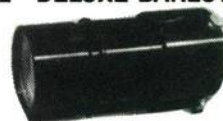
This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2 1/4" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces. Clear aperture = 1.8".

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2" DELUXE BARLOW



1.8x Multiplier Lens

The computer-designed LUMICON 2" Multiplier/Field Flattener multiplies the image scale in photography by 1.8x (f/4.5 becomes f/8). Use it with any LUMICON 2" EASY-GUIDER. Guide-stars also become much sharper to make guiding easier. This lens is optimized for f/4.5, but will work well with any optical system. It may also be used visually as a highly corrected 2" Barlow lens.

LUMICON 1.8x Multiplier Lens ... \$235.00

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FROM \$59.50



LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1 1/4"-1 1/2" above the telescope tube. Use the 1 1/4" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

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Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

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These adapters convert refractors and Schmidt-Cassegrain telescopes for 2" operation. They allow use of 2" accessories, such as the LUMICON 2" EASY-GUIDER for photography. They also allow use of 2" eyepieces and/or 2" star diagonal for viewing.
2" adapter for C-8, Meade 2080, etc. \$26.00
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North

The all-sky map shows
how the sky looks at:
9:30 p.m. on December 1
8:30 p.m. on December 15
7:30 p.m. on December 31
Planets are shown
at midmonth

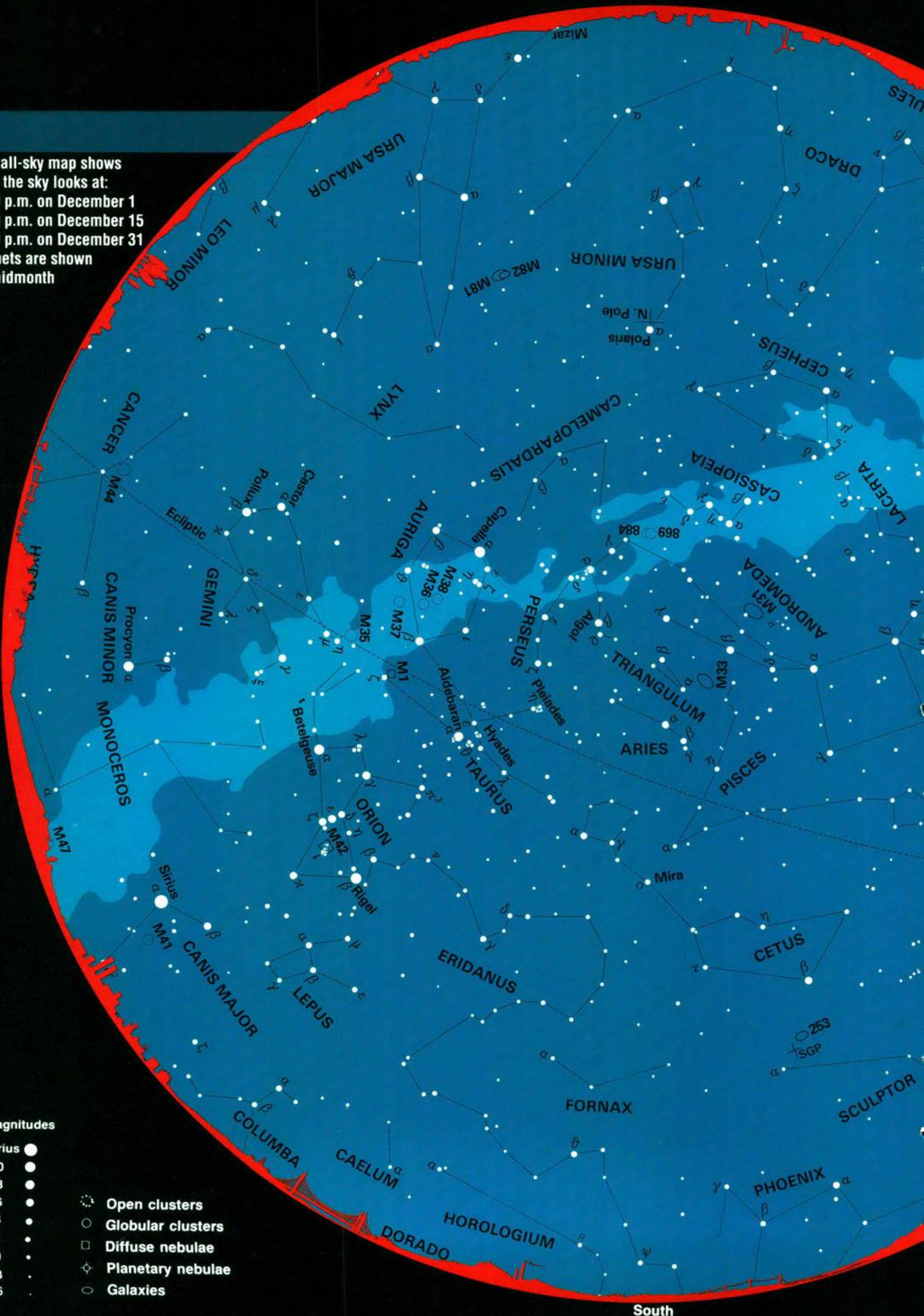
East

Magnitudes

Sirius ●
0.0 ●
0.8 ●
1.6 ●
2.4 ●
3.2 ●
4.0 ●
4.8 ●
5.6 ●

○ Open clusters
○ Globular clusters
□ Diffuse nebulae
◇ Planetary nebulae
○ Galaxies

South



Sky Almanac

December 1991

LUNAR ECLIPSE ON DECEMBER 21

The Moon skims the edge of Earth's umbral shadow on the morning of December 21, bringing a partial lunar eclipse to observers throughout North America and across the Pacific to eastern Asia and Australia. At eclipse maximum, a slim 9 percent of the Moon's disk is darkened by Earth's shadow.

GEMINIDS PEAK ON DECEMBER 14

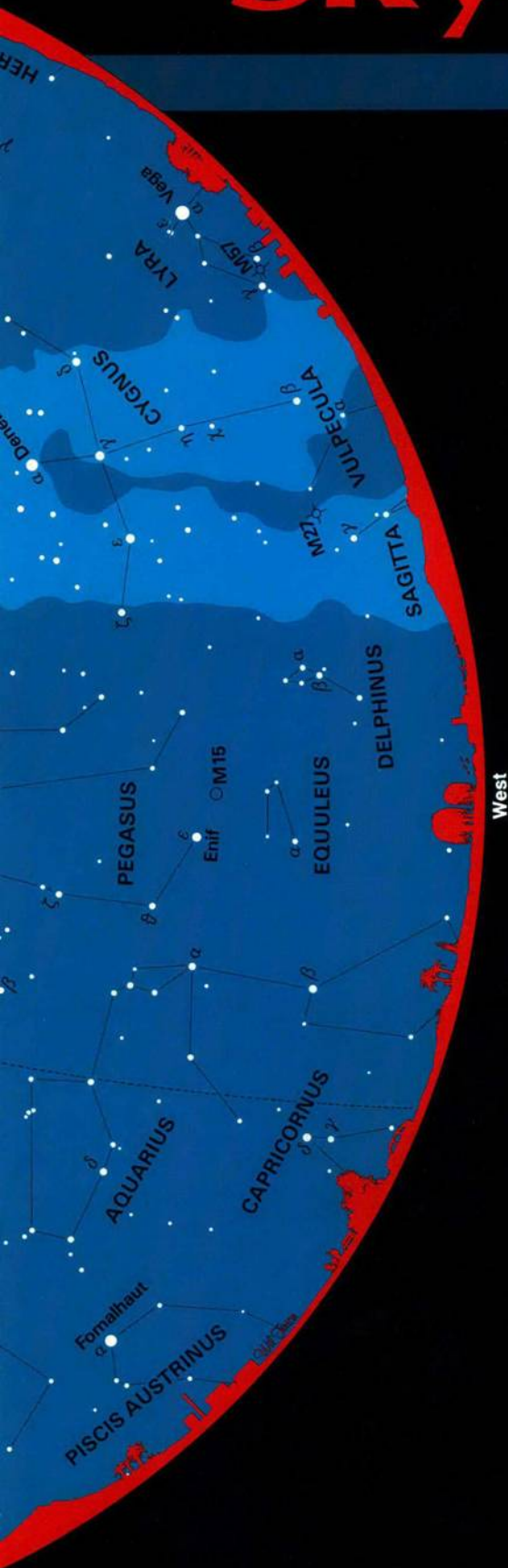
The Geminids should rival if not surpass the Perseids as the best meteor shower of 1991. The best viewing should occur on the morning of December 14, when the shower is at its peak and the First Quarter Moon has set. Expect to see up to 60 meteors per hour that morning from a dark-sky site.

MERCURY BRIGHT IN THE MORNING

The innermost planet puts in a good appearance in the morning sky during the second half of December. You can find Mercury low in the southeast — below and to the left of Venus — between 30 and 45 minutes before the Sun rises.

Calendar of Events

- | | |
|--|---|
| 5 New Moon is at 10:56 p.m. EST | 14 First Quarter Moon is at 4:32 a.m. EST
Geminid meteor shower peaks |
| 8 Mercury is in inferior conjunction | 21 Full Moon is at 5:23 p.m. EST; partial lunar eclipse |
| 9 The Moon is at apogee (252,167 miles from Earth), 8:51 p.m. EST | 22 Winter solstice is at 3:54 a.m. EST
The Moon is at perigee (222,671 miles from Earth), 4:26 a.m. EST |
| 10 The Moon passes 3° north of Saturn, 5 a.m. EST | 27 Mercury is at greatest western elongation (22°)
Last Quarter Moon is at 8:55 p.m. EST |
| 11 Mars passes 4° north of Antares, 10 a.m. EST
Ceres is in conjunction with the Sun | 31 Jupiter is stationary |
| 13 Mercury passes 3° north of Mars, 11 a.m. EST | |



DARKNESS TAKES A BITE OUT OF THE MOON

If clear skies prevail on the morning of December 21, early risers will be treated to a partial lunar eclipse. The good news is that the eclipse is visible from North America. The bad news is that it's the least spectacular partial lunar eclipse in over 30 years! At mid-eclipse (5:33 a.m. EST), only 9 percent of the Moon's disk lies in darkness. Still, the eclipse should be readily apparent to anyone with a clear view to the west that morning. In all, it takes the Moon about an hour to creep through Earth's shadow.

Lunar eclipses happen when the Moon traverses Earth's shadow. It's hard to believe that something as ephemeral as a shadow can look so black and sharp on the Moon's surface, and yet it does. If you look carefully, you will see traces of Earth's dusky outer shadow, or penumbra, fanning outward from the darker umbral shadow.

A lunar eclipse always happens at Full Moon, when the Sun and Moon are opposite each other as seen from Earth. This Full Moon occurs less than one day before the winter solstice, when the Sun is at its farthest point south in our sky. Thus the Full Moon lies farther north than any other this year and appears at its highest position in our sky as it arcs across the sky that night.

A FLURRY OF METEORS

On the night of December 13/14, Geminid meteors will streak across the sky as Earth plows through a region of space littered with debris left behind by a passing comet thousands of years ago. The Geminids — named for Gemini, the constellation from which they appear to radiate — are considered by many observers to be the best meteor shower of the year. In a dark country location, they produce about one meteor per minute at the shower's peak.

This is a good year for watching the Geminids, if you wait until after midnight. Aren't most meteor showers best after midnight? Yes, but the Geminids are usually the exception to this rule, because they encounter Earth's atmosphere at an unusual angle. They often produce a goodly number of meteors even during the evening hours. That's not the case this year, however, because the First Quarter Moon doesn't set until around midnight on the shower's peak night. Moonlight makes faint meteors hard to see, so wait until the Moon sets to start observing.

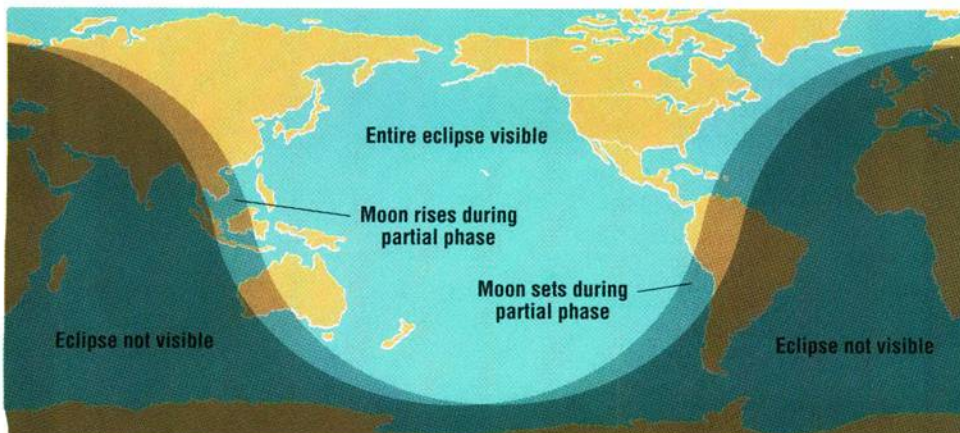
The usual rules for meteor watching apply: avoid the lights of the city; dress warmly; bring a thermos of something warm to drink; get up and move occasionally to keep your blood flowing; relax on a lawn chair or blanket; and gaze attentively in all directions so you see as many meteors as possible.

MERCURY RETURNS

The elusive planet Mercury has a good morning apparition this month. It passes between the Sun and Earth on December 8, then swings rapidly into view around midmonth low in the southeast. It grows brighter as the apparition progresses, because more of the planet's lit hemisphere then faces our direction. It shines at magnitude 1.3 around midmonth and by Christmas has brightened to magnitude -0.3 , when it is bright enough to be seen easily.



EARTH'S SHADOW GRAZES the Moon on December 21, affording viewers in North America, the Pacific, and eastern Asia and Australia the chance to see a 9-percent eclipsed Moon (below). The Moon should appear like it did when Andrew Steinbrecher captured the July 16, 1981 lunar eclipse (above).



DECEMBER'S PLANETS

Saturn lies low in the southwest after the Sun goes down this month. The 0.7-magnitude planet far outshines the stars of Capricornus, the constellation where it currently resides. But it won't be long before the ringed planet disappears into the Sun's glare; at midmonth it sets just three hours after sunset. Although Saturn is the faintest of the bright planets, I always miss its gentle golden glow when it's not there. Be sure to get a last good look at Saturn this month, shining behind the bare trees during evening twilight.

After Saturn sets, you won't see another planet until Jupiter rises shortly before midnight. The giant planet rides high in the south when dawn breaks, among the background stars of Leo the Lion and not far from the bright star Regulus. Jupiter shines brightly at magnitude -2.1 , in contrast to magnitude 1.4 Regulus. The planet is currently getting brighter, because Earth is now sneaking up on an inside track around the Sun and the distance between our two worlds is decreasing. We will pass between Jupiter and the Sun next February.

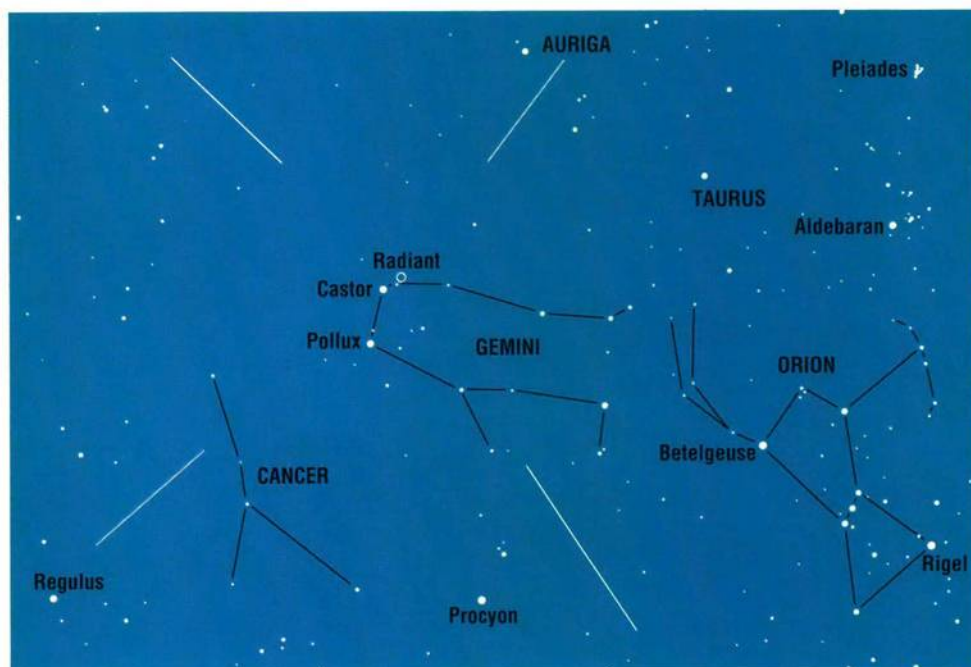
Venus opens the month in the predawn sky near the Moon and the bright star Spica. You can't miss Venus because it's the brightest thing in the sky besides the Sun and Moon. It shines at magnitude -4.2 this month. Venus is now about a month past greatest elongation, when it was highest in the sky before dawn. Over the coming months, it will sink slowly into the Sun's glare, but will remain a heart-warming beacon in the predawn sky throughout the winter.

Venus isn't the only planet in this part of the predawn sky. In the second half of December, another morning "star," innermost Mercury, lies to the lower left of this luminary. Mercury passes between Earth and the Sun on December 8 and then quickly shoots up into the predawn sky. It seems to creep up toward Venus during the third and fourth weeks of December, but never makes it. Even at greatest elongation on December 27, when it lies 22° west of the Sun, it never comes within 15° of Venus. After elongation, Mercury starts sinking back toward the Sun's glare again, but it remains visible until mid-January.

Long-lost Mars — gone these many months on a hiatus behind the Sun — returns to the predawn sky at the end of the year. The Red Planet has been traveling behind the Sun, but by year's end it moves far enough out from the Sun's glare to become visible again as a faint dot in the predawn sky. The 1.4-magnitude planet is distinctive because of its orange-red color. Don't confuse Mars with its old rival, the red star Antares in the constellation Scorpius. Antares comes out of the Sun's glare a week or so earlier than Mars and appears slightly higher and brighter than Mars.

THE STARRY SKY

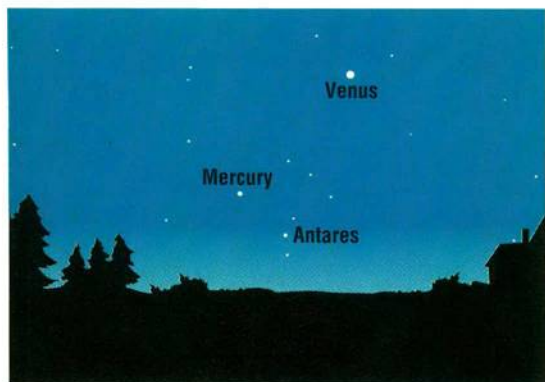
If you look high in the north on December evenings, you'll see the constellation Perseus the Hero. This constellation has such a dynamic shape — so fluid and graceful — that in 15 years of skywatch-



GEMINID METEORS STREAK across the sky on the morning of December 14, when observers can expect to see up to 60 meteors per hour.

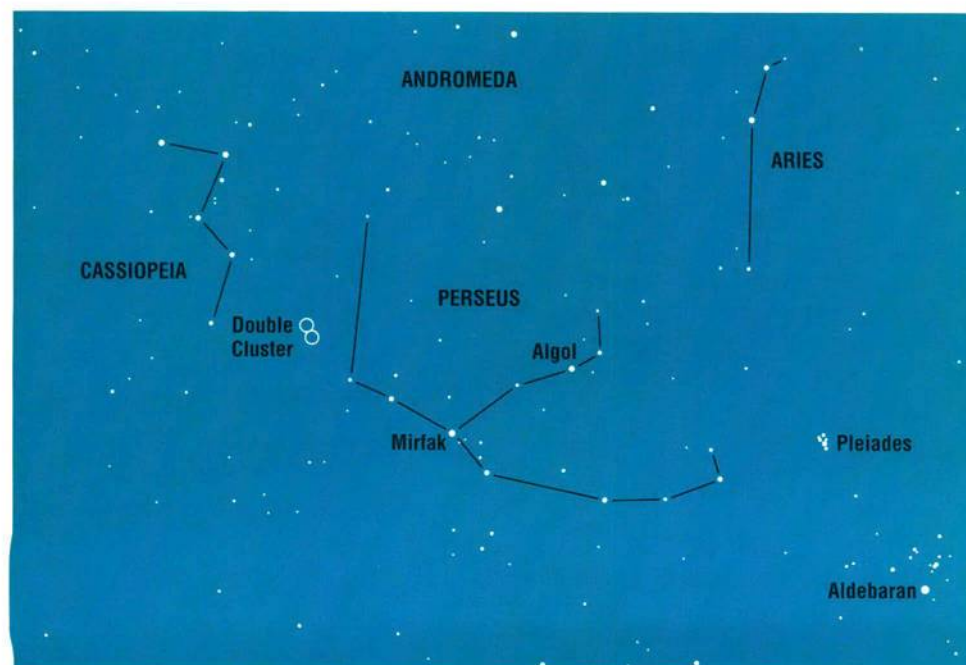
SATURN SINKS DEEPER into the twilight glow this month and will soon be lost from view. You can get a last good look at the planet around midmonth, when it lies low in the southwest during evening twilight.





TRACK DOWN ELUSIVE MERCURY in the week around Christmas, when it appears low in the southeast about 30 minutes before sunrise. Mercury lies about 20° to the lower left of brilliant Venus, which serves as a convenient guide.

BRIGHT STARS AROUND in the constellation Perseus. This conspicuous grouping of stars lies high in the north on December evenings, nestled between Cassiopeia and the Pleiades.



ing I've never gazed at it without thinking of the words "dancing Perseus."

By marriage, Perseus belongs to the sky's Royal Family, which also includes the Princess Andromeda, King Cepheus, and Queen Cassiopeia. As a young man, Perseus was given the task of killing the Gorgon Medusa, whose hair was a mass of writhing snakes. Anyone unlucky enough to gaze at Medusa was immediately turned to stone! That made her difficult to kill, but Perseus was favored by the gods. He was given an unbreakable magic sword and a highly reflective shield. Gazing in the shield to see Medusa indirectly, he cut off her head and placed it in a leather sack.

Afterward, Perseus put on a cap that made him invisible and flew away on winged sandals. The god of the ocean, Neptune, created the flying horse Pegasus for him from a mixture of Medusa's blood and sea foam. Perseus flew along the Ethiopian coast, where he saw the princess Andromeda chained to a rock, awaiting her fate in the jaws of a great sea monster. Of course, he rescued her and was given her hand in marriage. (See October 1991 for a more detailed account of this part of the legend.)

The brightest star in Perseus is Mirfak, which is also sometimes called Algenib. It is a white supergiant, shining at magnitude 1.8, and is located about 620 light-years away. Skywatchers who aim binoculars in the vicinity of Mirfak will find a scattering of hot young stars known as the Alpha Persei Association.

Beta Persei, or Algol, was once considered by astrologers to be the most unlucky, violent, and dangerous star in the heavens! Not surprisingly, it represents the Head, or Eye, of Medusa. It's also sometimes called the Ghoul Star.

For us, Algol is a glimpse into a realm where mighty suns move in orbit around one another. Most of the time, Algol is almost as bright as Mirfak, but some night you might gaze toward the star to find it more than a magnitude fainter than usual. Every 2 days, 20 hours, and 49 minutes, Algol gets dimmer for a period of about 10 hours. Then it gradually grows brighter again, only to fade again on schedule.

Algol is an eclipsing variable star. In other words, it's really two stars revolving around each other, eclipsing each other as seen from our earthly vantage point. When the brighter star is eclipsed, the system's light drops noticeably, and we see dimming.

Before leaving the vicinity of Perseus, also look for the famous Double Cluster, known as h and Chi Persei. These two adjacent star clusters lie between Cassiopeia and Perseus. On a dark night, they are visible to the eye as a hazy patch. As usual for a deep-sky object, binoculars give a better view, and telescopes reveal many colored stars — a veritable jewel box in the starry heavens. □

Deborah Byrd is writer, coproducer, and cohost of the nationally syndicated radio series Earth and Sky.

THE MOON IN ECLIPSE

On December 21, for the first time in over a year, the Moon passes through Earth's dark umbral shadow. Although only a small part of the Moon is in the shadow — at the peak 9 percent of the Moon's disk is darkened — the eclipse is easy to see if you have a clear sky and the Moon is above the horizon.

The Moon is perfectly placed for observers throughout North America. From there the Moon is well up in the west during the early morning hours, when the eclipse is at maximum. Meanwhile observers in much of South America can see the early stages of the event before the Moon sets. On the other side of the world, observers in parts of Australia and Southeast Asia can see the partially eclipsed Moon rise on the evening of December 21. (The map on page 60 shows where the eclipse is visible and the diagram at right gives the times of the eclipse.)

There are a variety of ways you can observe a lunar eclipse. To get a good general view, try sitting in a recliner and viewing with a pair of binoculars. This technique works well with binoculars up to 10x50 in size, but if you have larger binoculars, say 10X70s or 11x80s, you'll want to mount them on a tripod. For a closeup of the shadow's progress across the lunar surface, use your telescope and an eyepiece that yields a magnification of 100x to 175x.

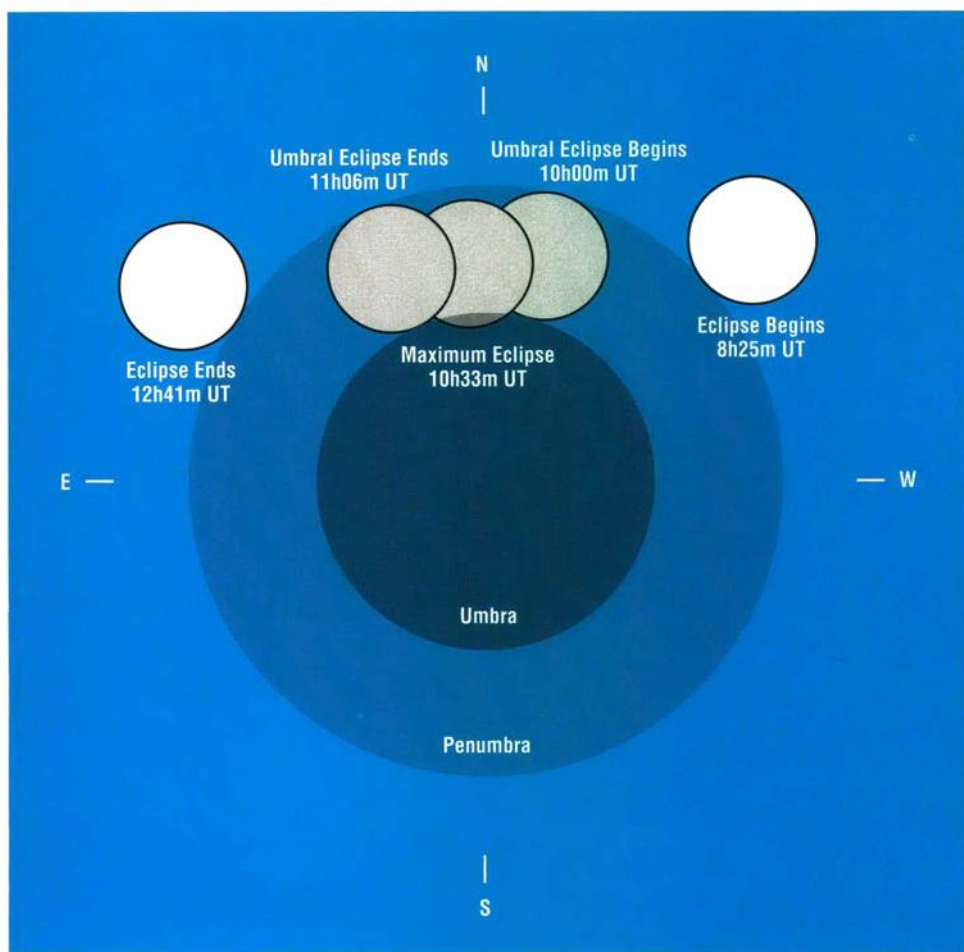
The major spectacle during most lunar eclipses is the color of the Moon. But with only 9 percent of the Moon immersed in Earth's shadow at this eclipse, the only "color" you're likely to see is grey. Count yourself among the eagle-eyed if you detect any hint of color in the eclipsed part.

Although a 9-percent eclipse may not sound like a lot, keep in mind that this is the fourth lunar eclipse of 1991 and it is easily the best. Three times previously — in January, June, and July — the Moon passed through Earth's penumbra — the lighter, outer part of our planet's shadow.

But as partial umbral eclipses go, this one is pretty slim. Not since May 3, 1958, when less than 2 percent of the Moon passed through the umbra, has there been a smaller eclipse.

MERCURY'S RAPIDLY CHANGING APPEARANCE

Much of the planetary action this month is in the morning sky. And one of the more elusive planets, Mercury, is a major player. The innermost planet comes into view around the middle of December and proceeds to put on a good show in the southeastern predawn sky. Mercury reaches the peak of this morning apparition on December 27, when it is at greatest elongation. The planet then lies 22° west of

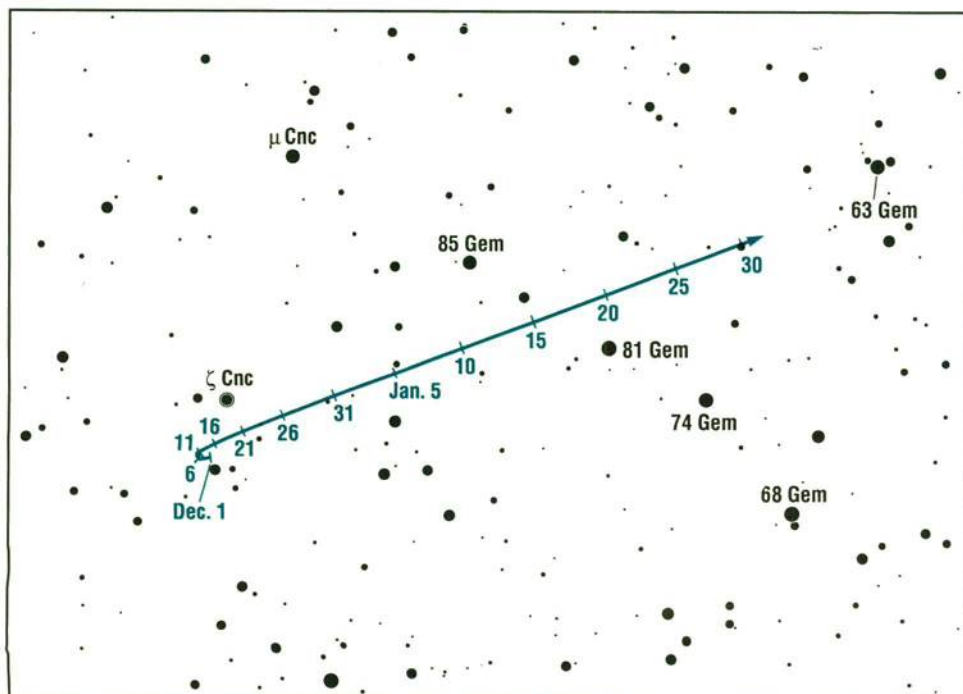


DARKNESS DESCENDS on 9 percent of the Moon during the partial lunar eclipse on December 21. All times are in universal time; subtract 5 hours to convert to EST, 6 hours for CST, 7 hours for MST, and 8 hours for PST.

COORDINATES FOR NYSA

Date	R.A. (2000) Dec.	
Dec. 1	8h13.4m	16°44'
Dec. 6	8h14.2m	16°44'
Dec. 11	8h14.1m	16°49'
Dec. 16	8h13.1m	16°57'
Dec. 21	8h11.2m	17°09'
Dec. 26	8h08.5m	17°25'
Dec. 31	8h05.0m	17°45'
Jan. 5	8h00.9m	18°07'
Jan. 10	7h56.2m	18°32'
Jan. 15	7h51.3m	18°57'
Jan. 20	7h46.4m	19°24'
Jan. 25	7h41.5m	19°49'
Jan. 30	7h37.1m	20°14'

ASTEROID 44 NYSA makes its way slowly through western Cancer this month before picking up speed and crossing into Gemini in January. Positions are shown for 4 a.m. EST (3 a.m. CST, 2 a.m. MST, and 1 a.m. PST).



the Sun and appears 12° above the horizon 30 minutes before sunrise. Mercury then starts to sink into the twilight glare, though it remains visible well into January.

The most interesting features of Mercury's telescopic appearance are its rapidly shrinking size and waxing phase. And these aspects change fastest during the first two weeks of the apparition. On the morning of the 15th, Mercury measures 9.0" across and shows a slender crescent that is just 18-percent lit. By the 23rd, the planet's disk has shrunk to 7.3" across and its phase has grown to half-lit. At greatest elongation just four days later, the 6.7"-diameter disk appears distinctly gibbous, with 63 percent of the Earth-facing hemisphere being illuminated. And at month's end, Mercury's disk has diminished to 6.2" across while its phase has waxed to 72-percent lit.

KEEP AN EYE ON JUPITER

Although Mercury is certainly worth watching, it can't hold a candle to Jupiter. The giant planet now rises before midnight and is high in the south as dawn approaches, well above the thickest layers of our atmosphere near the horizon that often cause bad seeing. Jupiter is also well on its way toward next February's opposition, so its disk now appears quite large. The planet's disk measures 38" across the equator in mid-December, far larger than any other planet. Jupiter's large size and high altitude mean that details in the Jovian atmosphere will be easier to see in a telescope than they have been for the past several months.

And there should be plenty of details to observe. The South Equatorial Belt (SEB), which just two years ago had faded to near invisibility, is now back to its former prominence. Unfortunately the Great Red Spot, which seemed to benefit from the SEB's fading, is quite a bit paler now than it had been. You can use the table of transit times on the opposite page to zero in on the Great Red Spot.

One of the best ways to improve your view of the Jovian atmosphere is to use a set of color filters. Try a light-blue filter to increase the contrast between the alternating bright zones and the darker belts.

Years ago when I first tried a light-blue filter with my 6-cm refractor, I could hardly believe how many more belts I could see at higher Jovian latitudes than I could without the filter.

To get a better view of the Great Red Spot, try a green filter. A green filter lets through very little red light but does transmit much of the light from the belts and zones, thus increasing the contrast between the Great Red Spot and its surroundings. As you gaze at the Red Spot, notice how big it is. The Spot's north-to-south size is roughly one-tenth that of Jupiter's polar diameter, which makes the Red Spot about the size of Earth.

Once you've examined the atmosphere of Jupiter, take a little time to enjoy the dance of the Jovian moons. As the satellites orbit Jupiter they pass both in front of and behind the planet, which cre-

ates eclipses, transits, and occultations. Because Jupiter is approaching opposition, when a satellite passes in front of the planet its shadow precedes it. What we see is the shadow of the satellite crossing Jupiter's disk before the disk transits. When a satellite goes behind Jupiter, we see it eclipsed by Jupiter's shadow before Jupiter occults the satellite's disk.

TELESCOPIC PLANETS

Venus is somewhat higher in the morning sky than Mercury this month, but it is much easier to see because it's so much brighter. At midmonth the planet lies nearly 30° above the southeastern horizon 30 minutes before sunrise and shines brilliantly at magnitude -4.2. Unfortunately for telescopic observers, Venus doesn't change appearance as rapidly as Mercury does this month or as rapidly as Venus itself has over the past several months. On the 15th, Venus displays a 17"-diameter disk that is 69-percent lit.

Mars finally returns to the morning sky in late December, appearing low in the southeast during morning twilight. At month's end, the 1.4-magnitude planet has a disk that measures 3.9" in apparent diameter, too small to show any detail in a telescope. Over the next few months Mars grows slowly in size, but it will be nearly a year before it reaches 10" in apparent diameter.

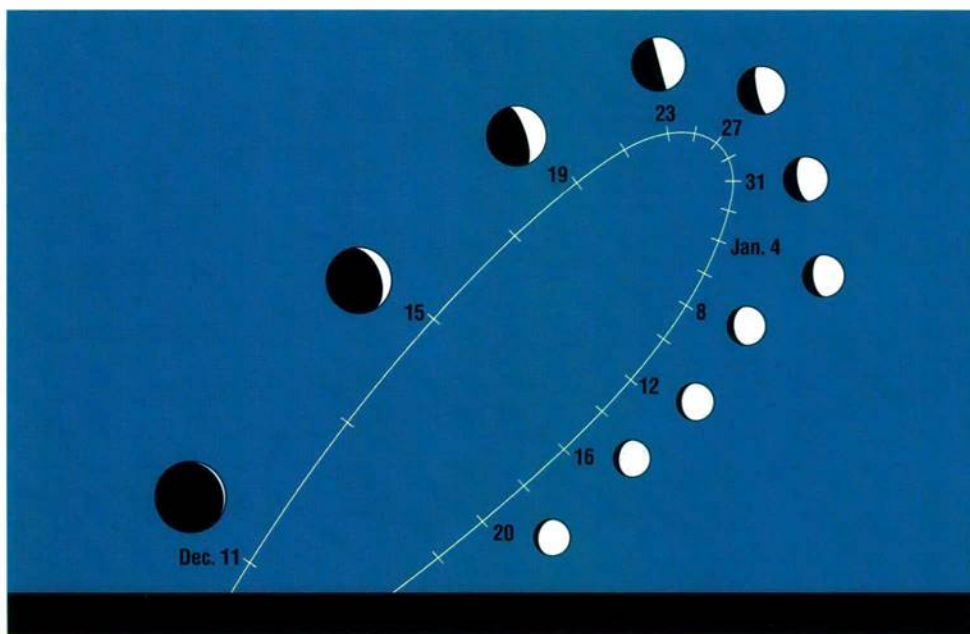
This is the last month for you to get a good view of Saturn in the evening sky. The ringed planet sets a bit over two hours after twilight ends on December 1 and just half an hour after twilight ends on the 31st, so it is not very high in the sky for very long. Still, the 35"-diameter ring system is gorgeous under even relatively poor conditions and well worth a quick look in the early evening.

Saturn's celestial companions, Uranus and Neptune, are even closer to the horizon after sunset than Saturn is. You'll need to observe them at the beginning of the month to get much of a view at all. All you can expect to see of Uranus is a 3.4"-diameter, blue-green disk that glows at magnitude 5.8. Neptune is even harder to get a good view of — it's an 8th-magnitude, blue-gray disk just 2.2" in diameter.

ASTEROIDS IN THE EYEPIECE

Although asteroid 44 Nysa reaches opposition in mid-January, it is bright enough to spot fairly easily this month also. The table of coordinates and map at left will get you to the asteroid's approximate position. Zero in on that region with a medium-power eyepiece and look for the "star" that doesn't belong. To confirm your sighting, photograph or sketch the field and then return to the same region the following night. The point of light that has moved slightly is Nysa. □

Rick Shaffer is a technical group leader at the Jet Propulsion Laboratory in Pasadena, California. He leads the data management team on the Ulysses mission, a spacecraft closing in on Jupiter before heading ultimately to the Sun.



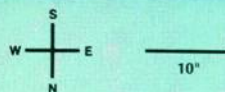
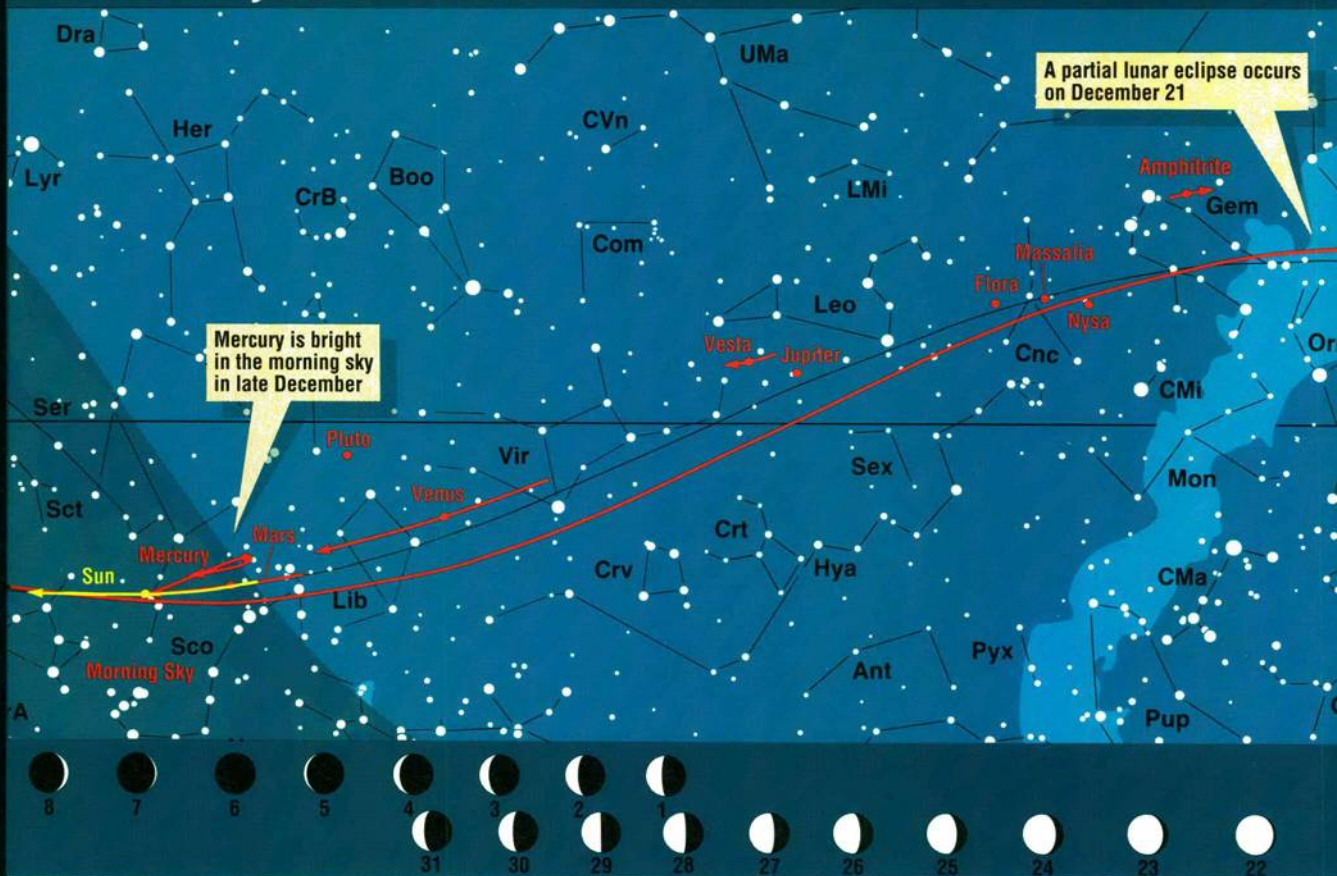
MERCURY SHOOTS UP from the southeastern horizon in mid-December and lies more than 10° high 30 minutes before sunrise during the latter half of the month. Its rapidly changing size and phase are always fun to follow with a telescope. (Disk views are shown with south at top to match the view in an inverting telescope.)

GREAT RED SPOT TRANSIT TIMES

Date	Time
December 1	3:13 a.m.
December 3	4:52 a.m.
December 5	6:30 a.m.
December 6	2:22 a.m.
December 8	4:00 a.m.
December 10	5:38 a.m.
December 13	3:08 a.m.
December 15	4:46 a.m.
December 17	6:25 a.m.
December 18	2:16 a.m.
December 20	3:54 a.m.
December 22	5:32 a.m.
December 23	1:24 a.m.
December 25	3:02 a.m.
December 27	4:40 a.m.
December 29	6:18 a.m.
December 30	2:09 a.m.

The Great Red Spot can be seen for two to three hours before and after the transit times listed. All times are EST; subtract 1 hour to convert to CST, 2 hours for MST, and 3 hours for PST.

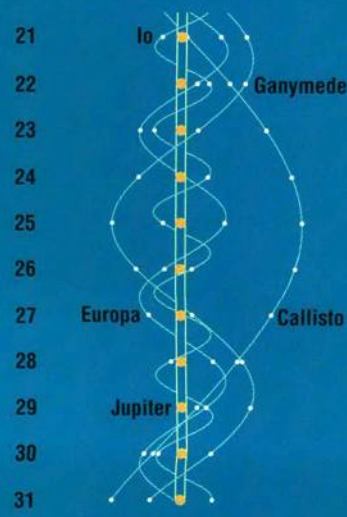
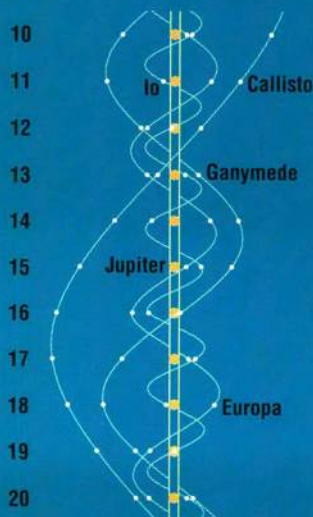
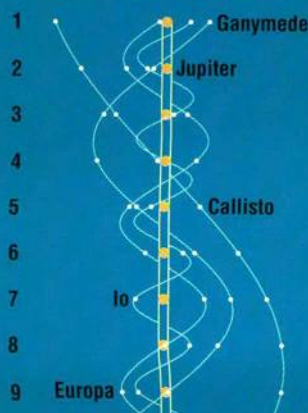
The Solar System December 1991



Planet	MERCURY	MERCURY	VENUS	MARS
Date	December 1	December 31	December 15	December 31
Magnitude	+1.0	-0.3	-4.2	+1.4
Angular Size	8.9"	6.2"	16.6"	3.9"
Illumination	21%	71%	69%	99%
Distance (AU) from Earth	0.759	1.079	1.003	2.416
Distance (AU) from Sun	0.326	0.404	0.719	1.494
Right Ascension (2000.0)	17h33.0m	17h04.1m	14h34.5m	17h30.1m
Declination (2000.0)	-24°15'	-21°14'	-12°39'	-23°43'

Jupiter's Moons

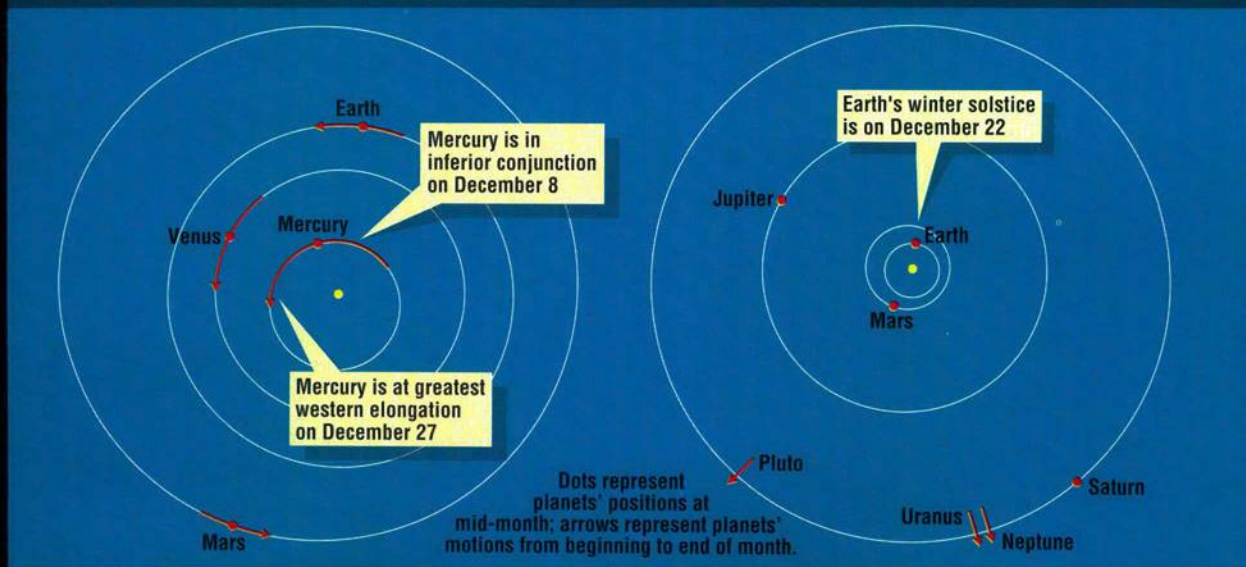
Dots display positions of Galilean satellites at 9 UT on date shown. South is at top to match the view in a telescope.

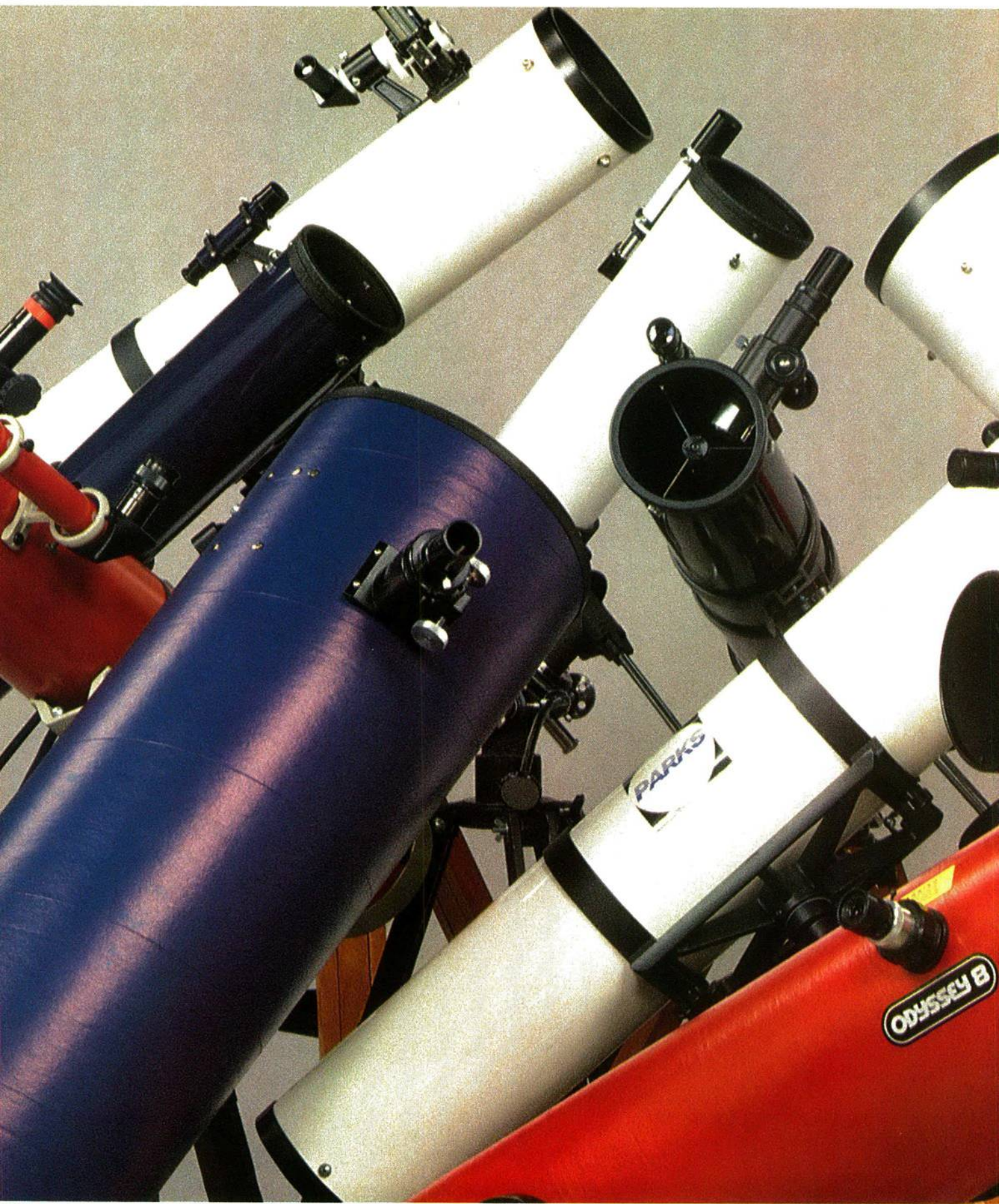




JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
December 15	December 15	December 15	December 15	December 15
-2.1	+0.7	+5.8	+8.0	+13.8
38.2"	15.5"	3.4"	2.2"	0.1"
99%	100%	100%	100%	100%
5.154	10.654	20.427	31.098	30.498
5.385	9.939	19.506	30.195	29.686
11h04.0m	20h26.6m	18h55.8m	19h07.8m	15h31.8m
7°11'	-19°46'	-23°11'	-21°47'	-4°09'

The Planets in Their Orbits





ASTRONOMY

Tests Affordable Reflector Telescopes

We tested 12 Newtonian reflector telescopes, each costing less than \$1,000. We found several good choices for an entry-level scope, including a couple of bargains. We also found some lemons.

by Alan Dyer

In this review we set out to find well-made but relatively affordable telescopes for the first-time buyer. We are pleased to announce that we found several that we can recommend.

Each of the dozen telescopes in this review is a Newtonian reflecting type (the kind that uses mirrors to gather and focus the light) and each commonly retails at most dealers and mail order outlets for under \$1,000. We evaluated each telescope within its aperture class: 4.5-inch models, 6-inch models, and larger-aperture models (8- and 10-inch). Because of its unique mount, we reviewed the Coulter Odyssey 8 in a class by itself.

Despite the range of apertures, the price limit we set means that all the test scopes are potential choices for someone getting started in astronomy. Higher in price you encounter the 8-inch Schmidt-Cassegrains, a portable design that over the last two decades largely replaced the traditional equatorially mounted Newtonian that so dominated the hobby before 1970. But Schmidt-Cassegrains start at \$1,000. What if you don't wish to spend that much? You can buy a 3-inch refractor (the lens-type of tele-

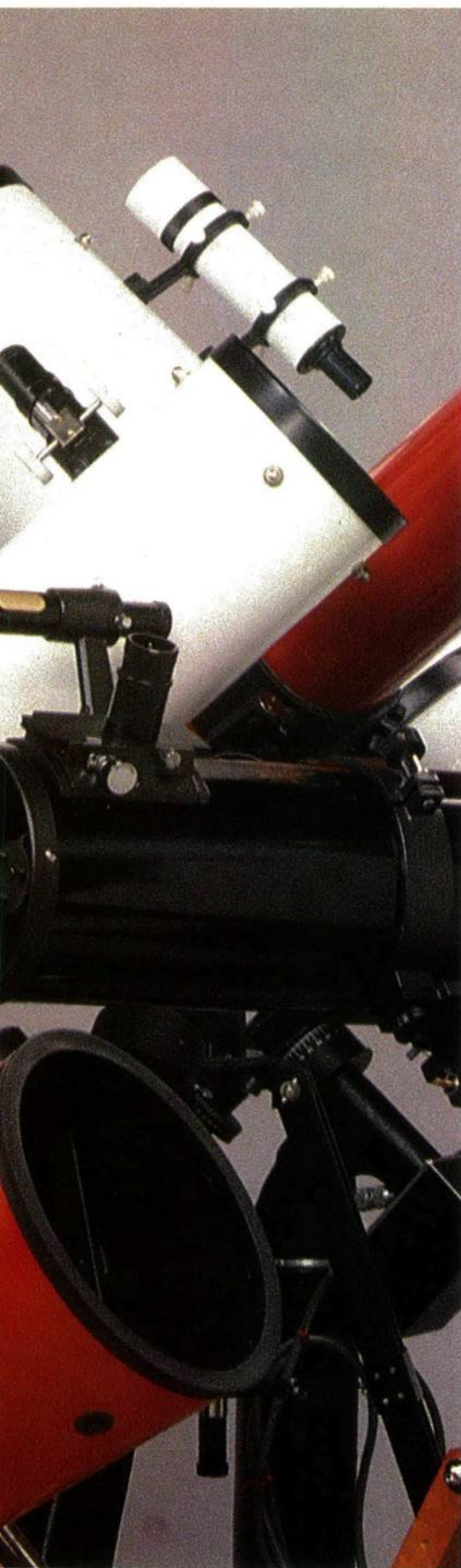
scope), perhaps even a 3.5-inch, for under \$1,000. But what if you want more aperture? The answer may be a Newtonian reflector.

Newtonians have long proven themselves as far more than low-cost beginners' scopes. They can also please even discriminating optical aficionados by offering sharp, contrasty views of planets and deep-sky objects. If you compare a good Newtonian to a refractor of the same aperture, the refractor usually comes out the winner. But when you put a good Newtonian against a refractor of the same price, there's usually no contest. The larger-aperture Newtonian wins.

As an example of refractor vs. reflector, we matched a \$4,500 4-inch apochromatic refractor with the \$850 Parks 6-inch f/8 Newtonian, a classic long-focus design that should provide great views of the planets. It should and it did. In the Newtonian the image of Saturn was brighter (as you would expect in a 6- versus 4-inch test), but also exhibited greater color contrast between the A and B rings, and between the belts and zones of the planet itself. The black line of Cassini's division in the rings was etched all around the rings with cleaner definition. All in all, the Newtonian telescope provided more pleasing planetary views — at less than a fifth of the price!

Good optics, generous aperture, and reasonable price — that's what the classic Newtonian is capable of delivering. Did the models we tested live up to the potential? Read on to find out.

YIKES! IT'S MIRROR MADNESS! We tested reflecting telescopes costing less than \$1,000, ranging in size from 4.5 inches to 10 inches. Of the dozen telescopes we examined, a few stood out from the crowd for quality and value.



4.5-inch Telescopes



THE MOUNTS FOR THE 4.5-INCH SCOPES range from acceptable to excellent. The mount (at top) used on the Tasco and Orion Spaceprobe proved to be shaky but usable. The Meade version of the same basic mount (bottom) was slightly steadier. The Celestron C4.5's Vixen Polaris mount (top right) was the solid winner.

The population of today's backyard astronomers that started their celestial hobby with a 4.5-inch reflector probably numbers in the tens of thousands. Chances are it was a Tasco, the 11TR, a model that has been on the market for at least 20 years.

We paid \$496 for our test unit Tasco 11TR. (Very similar models are available from Jason Empire, Swift, and Simmons, as well as from many department and camera stores as "house brands.") For \$496 (it may sell for less at some outlets), you get a well-finished telescope on a mount that is wobbly but acceptable. Because it is an equatorial design, the mount can follow a celestial target conveniently with one smooth motion as it arcs across the sky. The mount has good locks and slow-motion controls (features we like since both make aiming the telescope much easier) but the flexible slow-motion cables bounce back and forth, imparting vibration to a mount that shakes at every touch. After a mild

rap to the tube of the Tasco (a test we applied to every telescope), the image in the eyepiece took 5 to 6 seconds to stop dancing around. (We consider 2 to 3 seconds of settling time good and 5 to 6 seconds passable.)

The finderscope (the small sighting scope on the side of the tube that helps you aim the main scope) on the 11TR is advertised as a 5x24, meaning a 5-power model with a 24mm aperture front lens. However, even though the lens is 24mm across, a diaphragm just inside the finder's lens effectively stops down the lens to only 10mm aperture. When peering through such a tiny aperture it is difficult to see anything except the brightest stars. The included eyepieces, a 20mm and a 4mm, are of poor quality. They exhibited narrow fields, chromatic aberration (or color fringing), poor eye relief and, in the case of the 4mm, far too high a power for most purposes. The Barlow lens (which doubles the power of any eyepiece) was similarly poor — it added significant chromatic aberration around bright objects. When coupled with the 4mm eyepiece, the Barlow yielded 450 power, a magnification you would rarely use on even the largest and best telescopes.

On the Tasco we purchased, the quality of the main optics rated an average "C" — they exhibited textbook spherical aberration, the same aberration that troubles the Hubble Space Telescope. When viewing Saturn (planetary detail is a tough test of optics), the image was noticeably fuzzy, especially when we compared it to the view through the competing models.

In all fairness, the average Tasco 11TR's optics may rate better than the one we tested. We say this because the Orion Spaceprobe (from the Orion Telescope Center) and the Meade 4420 (from Meade Instruments Corporation) — two very similar models (perhaps even made at the same plant) — both proved to have good B+ optics. Both showed only a trace of spherical aberration. The Orion and Meade gave satisfyingly sharp images of Saturn. At high power (180x), stars presented a clean Airy disk surrounded by a faint but well-defined first diffraction ring, an indication of good optics.

Quite frankly, we were impressed with the optical quality of the Meade 4420 and Orion Spaceprobe. We can't be sure if the poor showing from the apparently

identical Tasco was a consistent brand-to-brand difference or a random unit-to-unit variation.

To their credit, Orion and Meade have both taken the basic Tasco-style instrument and offered it with intelligent improvements. Orion's \$399 version has better eyepieces than the Tasco (25mm and 9mm Kellners, both providing useful magnifications and wider fields). The Orion also has a much better finderscope, a 6x30 model held in a 6-point bracket that is easier to adjust than the 3-point support used by Tasco. Our unit from Orion came with a right-angle finder, a style we dislike because it provides a confusing mirror-image view of the sky. When we inquired about this, Orion told us the latest Spaceprobes now come with straight-through finders and 1¼-inch diameter eyepieces instead of the 0.965-inch ones that came with our purchased test sample.

Meade's version offers different improvements. Although it has the same poor 5x24 finderscope as the Tasco, the finder is held in a better 6-point bracket. The focuser will accept 1¼-inch eyepieces. The Meade comes with one good-quality Kellner-class eyepiece (a 25mm) and to their credit Meade has dropped the poor-quality Barlow from their package. The Meade's mount was similar to the mounts from Orion and Tasco but had a touch better damping time (4 to 5 seconds), perhaps because of the use of square leg extensions on the tripod instead of round legs as on the Orion and Tasco models.

The Meade goes for \$300 to \$350 from most outlets. At \$300, we consider the Meade 4420 to be the best buy — good optics on a usable equatorial mount for a bargain price — in all, a good beginner's scope. Although it is more expensive, we can also recommend the Orion Spaceprobe.

The final scope in the 4.5-inch entry-level class is the Celestron/Vixen C4.5. It is the most expensive, selling for \$450 to \$550 from most dealers. (Celestron has recently introduced new lower-priced 4.5-inch reflectors, the Vixen alt-azimuth #9115 and equatorial #9117. These were not available when we conducted our review.) However, the C4.5 stands out from the pack by having by far the best mount. Its Vixen Polaris mount is wonderful. Solid. Smooth. Great slow-motion controls. And with a damping time of 2 seconds. It was a joy using this telescope. Optically,



THE FINDERS AND FOCUSERS varied considerably. The Tasco (top left) and Celestron (top right) used a poor 5x24 finder but the Celestron had a good 1¼-inch focuser. The Meade (bottom left) had a poor 5x24 finder but it was mounted in a bracket with a good 6-point adjustment. Its focuser also accommodated 1¼-inch eyepieces. The Orion (bottom right) had the best finder (a 6x30) but the same 0.965-inch focuser as the Tasco.

MODEL	OPTICS	MECHANICS	RATING	RETAIL	VALUE	WEIGHT (lbs)
Celestron C4.5	B	Excellent	☆☆☆☆	\$500	Good	26
<i>Best mount in its class but undersized secondary effectively reduces aperture.</i>						
Meade 4420	B+	Fair	☆☆☆	\$300	Excellent	21
<i>BEST BUY at less than \$350. Good optics on a usable mount at a bargain price.</i>						
Orion Spaceprobe	B+	Fair	☆☆☆	\$399	Very good	23
<i>Same scope as Meade 4420 but with two eyepieces and a better finderscope.</i>						
Tasco 11TR	C	Fair	☆☆	\$500	Fair	23
<i>Similar to Meade 4420 and Orion but with higher price and worse eyepieces and finderscope.</i>						
<i>See page 75 for an explanation of rating terms.</i>						

the C4.5 tested as having apparently grade A optics — star images were classic textbook Airy disks, and Saturn looked sharp and crisp. Except one thing: in a side-by-side comparison with the Meade, Orion, and Tasco, all three competitors had noticeably brighter images.

The reason for the dimmer images lies in the fact that the C4.5 projects the focus point farther out from the side of the tube. This is probably done so the telescope can accommodate a camera. However, the C4.5 should therefore have a larger secondary mirror to intercept the entire light cone coming from

the main mirror. But it doesn't. The secondary is the same size as those in the three other 4.5-inchers. As a result, light is lost around the secondary, cutting the C4.5 down (by our calculations) to an effective aperture of 3.8 inches.

The vignetted optics (for which we downgraded the C4.5's optical performance to grade B) and its poor 5x24 finder (though it has a true 24mm aperture), are the two important drawbacks to the C4.5. In other respects this is a first-rate telescope that outclasses the competition in the popular 4.5-inch class of Newtonian but at a higher price.

6-inch Telescopes



A GREAT 6-INCH TELESCOPE (pictured below) proved to be the Parks f/8 matched to the Super Polaris mount (the Parks "Astrolight" version) but on the Celestron's low tripod.



The next step up in aperture and price is to a 6-inch reflector. Back in the 1960s the 6-inch f/7 or f/8 Newtonian, such as the venerable Criterion RV-6 Dynascope, was the workhorse telescope for beginners and veterans alike. Today, the unglamorous and neglected 6-inch Newtonian is still a potentially ideal starter scope, one that is due for a comeback.

Lately, Parks Optical has been promoting an extensive lineup of classic Newtonians, including some 6-inchers under \$1,000. We purchased two for review: their long-focus f/8 on the Parks "Precision" mount, and their shorter f/6 on the Vixen Super Polaris mount, a version Parks dubs the "Astrolight." Parks also offers the f/6 on the Precision mount or the f/8 on the Super Polaris mount. The Super Polaris-mounted versions cost \$850. We paid \$800 for our Precision-mounted model. Parks has recently reduced the Precision models to \$700.

The Parks Precision mount is a throwback to the 1960s. The mount and steel pier alone weigh a back-breaking 49 pounds. For the labor of lugging this weight around you get a mount that takes 8 to 9 seconds (with the long f/8 tube) to damp out from a mild tap to the tube. The Precision mount does move quite smoothly with very little slop or backlash, allowing you to easily nudge the scope to fine-tune the aiming. But for stability, porta-

bility, and ease of setup, alignment, and aiming, the Precision pales in comparison to the 27-pound Super Polaris mount that Parks also sells.

When we mated the Parks 6-inch f/8 tube with the Super Polaris mount (creating an f/8 Astrolight), we found the damping time to be a much-improved 4 to 6 seconds. Placing a set of vibration dampening pads under the tripod legs (something only possible with tripod-mounted scopes) reduced this to 2 to 3 seconds.

When judging the optical quality in our pair of Parks telescopes we found that the f/8 had great optics, an A- on our scale. This is just what such a classic system with its small 23-percent secondary obstruction is capable of delivering. Star images exhibited clean, symmetrical Airy disks with nearly identical diffraction patterns either side of focus (indicating little spherical aberration or problem with zones). Saturn was sharp enough in this 6-inch Newtonian to outdo a 4-inch apochromatic refractor.

The Parks f/6 tube assembly was a more complex story. Theoretically, f/6 optics can provide as good an image as f/8 optics, though with a slightly larger central obstruction (26 percent in our f/6 model). Indeed, we received an f/6 mirror that proved to be excellent, an A- on our scale, confirming our expectations that on the Super Polaris mount the Parks 6-inch f/6 can be a compact but superb all-purpose telescope.

However, this top-notch performer was the telescope's second mirror. The original f/6 Astrolight we ordered from Scope City (Parks' retail outlet) exhibited astigmatism so severe it was impossible to get a sharp star image. Out-of-focus diffraction patterns were long ellipses; in focus, a star looked like a mushy cross. By rotating the primary mirror and loosening the fittings on the mirror cell (to relieve possible mechanical flexure) we determined the fault appeared to be in the figuring of the main mirror itself. We gave this original mirror a grade of D.

In other respects we were impressed with the quality control exhibited by Parks — for example, each packing list and mirror is signed. But something went wrong with our first mirror. We pointed out the defective mirror to Gary McDonald, chief optician at Parks, and a new mirror was shipped to us the same day. Maurice Sweiss, presi-

dent of Parks Optical, also informed ASTRONOMY that Parks has since instituted a further final optical check to ensure that defective mirrors such as ours do not escape again, a commitment to quality control that we applaud.

A model similar to the Parks f/6 Astrolight is Celestron's SP-C6, a 6-inch f/5 Newtonian made by Vixen on the ubiquitous Super Polaris mount. Damping time was 4 to 5 seconds (2 to 3 with vibration dampening pads). The focuser was a unique arrangement for commercial scopes — the focuser moves the entire secondary mirror back and forth. This works well, though we found a slight image shift at high power. The secondary mirror is a 2-inch model providing a whopping 33-percent obstruction. The oversized secondary is no doubt provided to fully illuminate a 35mm film frame and, indeed, with its f/5 speed and fittings for piggyback cameras and guidescopes, the SP-C6 is well-suited for deep-sky photography. However, to take full advantage of the light cone for prime focus photography, the SP-C6 should have a 2-inch focuser, not the image-vignetting 1½-inch model it comes with. As it is, for purely visual use, the secondary obstruction is far larger than it need be.

In optical tests the SP-C6 proved to have noticeable astigmatism, giving it a C+ rating. Star images were always a little fuzzy and Saturn never snapped into sharp focus during our testing. After discussing this with Alan Hale of Celestron, we were shipped a second telescope (our first was purchased from Pauli's Wholesale Optics) but it, too, proved to have slight astigmatism that would not go away even after loosening the mirror's clips. In a side-by-side comparison, our artificial star did not look as cleanly defined as it did in the competitive Parks f/6 mirror (the better one). In all other respects, we liked the solid SP-C6, but the optics of these two units were disappointing.

Our final 6-inch was the Edmund Model #3011, a 6-inch f/6. It had excellent optics (grade A-) but again we found an unnecessarily large secondary mirror, even for an f/6 photo instrument, that gave a 32-percent obstruction.

The equatorial mount for the Edmund was the worst we encountered in this review. The mount took 5 to 7 seconds to damp out. What's more, there was a 1° to 2° backlash in right ascension even when the

MOUNTS ARE MORE CRITICAL than many first-time buyers believe. The Super Polaris mount (bottom), used on the Celestron SP-C6 and Parks Astrolight models, is a solid performer. The Parks Precision mount (top right) proves that sheer weight does not make for a steady mount. The Edmund mount (bottom right) was the least convenient of the mountings we reviewed.



MODEL	OPTICS	MECHANICS	RATING	RETAIL	VALUE	WEIGHT (lbs)
Parks 6" f/8 Astrolight	A-	Excellent	☆☆☆☆	\$850	Good	45
<i>Mounting f/8 tube on Super Polaris Astrolight mount gave an excellent combination.</i>						
Parks 6" f/6 Astrolight	A-	Excellent	☆☆☆☆	\$850	Good	42
<i>More compact than f/8 though not as suited for planetary viewing. Original had defective optics.</i>						
Celestron SP-C6	C+	Excellent	☆☆☆	\$800	Fair	44
<i>Excellent mount but two test units' optics suffered from slight astigmatism defect.</i>						
Parks 6" f/8 Precision	A-	Fair	☆☆☆	\$700	Fair	67
<i>Excellent optics but mount was heavy and shaky. Same applies to f/6 Precision.</i>						
Edmund 6" f/6	B+	Poor	☆	\$875	Poor	40
<i>Good optics (but with oversized secondary mirror) on very wobbly mount.</i>						
<i>See page 75 for an explanation of rating terms.</i>						

axis was properly tightened. The lock on the declination axis would loosen whenever the scope was nudged, allowing the scope to swing unchecked in declination. The included AC drive motor took a minute or more to engage after every repositioning of the mount. (Only the Edmund 6-inch and Meade 8- and 10-inchers come with motor drives as standard.) The tube is held in the cradle by a pair of plastic straps that fails to hold the tube tightly enough — when we used it, the tube constantly slid down the cradle. The latitude bolt also came loose allowing the entire mount to flop down. Because of these prob-

lems in performance, we can't recommend the Edmund 6-inch.

In the 6-inch class, our recommendations are the Parks f/8 or f/6 tube assemblies on the Super Polaris mount (the "Astrolight" versions). The f/8 excels at planetary viewing, while the f/6 is better for deep-sky viewing and astrophotography. However, both were much easier to use when placed on the stubby tripod that came with the Celestron SP-C6 (the Parks tripod was inconveniently tall for even the f/6 tube). At \$850 we can't call the Parks Astrolights best buys, but they were the best we found in their aperture class.

Large-aperture Scopes



THE MEADE MOUNT, used on the 826C and DS-10A models, is a lightweight, no-frills platform that performed well on the economical 8-inch but was not as easy to use when coupled to the heavier 10-inch.

If you are seeking more aperture than a 6-inch but want to retain an equatorial mount to track the stars, two telescopes stand out in the under \$1,000 range. Both are Meades: the Model 826C (an 8-inch f/6), and the DS-10A (a 10-inch f/4.5).

Compared to the cost of the 6-inch models, these two scopes are bargains. In the two units we purchased (from Pauli's), we were pleased to see good optical quality. The Meade 8-inch optics rated a superb A-. There was just a hint of astigmatism, but during moments of steady seeing Saturn appeared very sharp.

The DS-10 rated a very good B+, showing sharp in-focus star images but slightly ill-defined diffraction rings either side of focus. Nevertheless, Saturn looked bright and crisp, proving that fast Newtonians do not have to be fuzzy light buckets.

Both telescopes come on the same basic Meade mount with an

AC clock drive. The mount is fairly steady but does not have features such as slow-motion controls. The 8-inch mount does include leveling screws on the legs, a latitude scale, and a fine adjustment on the latitude setting. The DS-10 lacks these niceties. Damping time for the 8-inch was an average 5 to 6 seconds. For the heavier 10-inch it was a surprisingly good 3 seconds.

Because its tube attaches directly to the mount (no tube rings) the DS-10 was difficult to balance properly. Combined with a weak declination lock, the lack of balance tended to make the scope swing off in declination too easily. There was also backlash in the right ascension axis (to center an object, you had to move an object off-center and let it fall back into the center of the field), and the drive did not kick in for 15 seconds by which time the object had drifted to the edge of a high-power field. We discussed this with Meade, and following their advice we tightened the drive clutch as far as we could without making the telescope difficult to move in RA. This improved the drive slack to 8 seconds, close to the 5 to 6 seconds Meade told us was normal for this mount. Nevertheless, the constant fussing to center targets was an inconvenience.

On the other hand, the 8-inch, though less steady, was easier to balance, had a firmer declination lock, and had a drive that engaged immediately. When you centered an object it stayed centered. Less fussing with the mount meant less chance for vibration to be imparted to the image. In all, the 8-inch was easier to use than the DS-10.

The 8-inch also comes with an 8x50 finderscope, the best we found on any of the scopes we tested. With the DS-10 a finder is optional — we strongly recommend one. We also would have preferred to see the counterweights on each scope held on with large bolts with hand-knobs instead of hard-to-reach Allen screws.

At \$750 the DS-10A represents a good value for the aperture-hungry deep-sky fan who wants an equatorial mount and drive. It is primarily designed to be a visual instrument but its fast f/4.5 speed would allow some limited deep-sky photography. However, neither Meade nor we would recommend the DS-10 as a first choice for astrophotography.

At \$800, the 826C seems like less aperture for more money. But we like the 826C and feel that the better optical and mechanical quality of the unit we tested makes up for the difference in aperture.

MODEL	OPTICS	MECHANICS	RATING	RETAIL	VALUE	WEIGHT (lbs)
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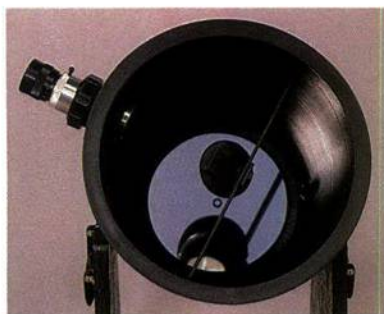
EQUATORIALLY MOUNTED TELESCOPES

Meade 826C 8" f/6	A-	Good	☆☆☆1/2	\$800	Good	64
<i>Excellent optics on a no-frills equatorial mount that is fairly steady and includes a motor drive.</i>						
Meade DS-10A 10" f/4.5	B+	Fair	☆☆☆	\$750	Good	77
<i>Very good optics. Bargain priced equatorially-mounted 10" scope with a clock drive.</i>						

DOBSONIAN-MOUNTED TELESCOPE

Coulter Odyssey 8	B-	Good	☆☆☆1/2	\$275	Excellent	43
<i>BEST BUY. Good optical quality on a steady, no frills Dobsonian mount.</i>						

The Odyssey 8



THE LOW-COST ODYSSEY 8 rates ☆☆1/2 for optical and mechanical quality, but rates an Excellent! for its value, making it a best buy. The fittings and finish are crude but effective. For example, the focuser (top left) is a sliding tube with a plastic collar to vary the friction or lock the eyepiece in place. The secondary mirror is glued directly to a hefty piece of metal for support.

For apertures 8 inches and over it is possible to maintain portability and convenience by sacrificing the equatorial mount altogether. One alternative is a Dobsonian-mounted telescope. This style of mount allows the scope to swing easily up-and-down and side-to-side but cannot track the stars along one axis of motion. You must continually nudge the scope to re-center an object. This is not a hardship since, when well-made, Dobsonians are very easy to move yet provide a solid vibration-free platform, all at low cost.

The price leader in Dobsonian scopes is Coulter Optical. For under \$1,000 you can buy a Coulter 8-, 10-, or even a 13.1-inch scope. The larger scopes are in heavy demand, with waits as long as 10 months for the 10-inch model. For this review we purchased an 8-inch from the factory and received it within the promised 4 weeks delivery time. The price? \$275, the lowest price of any of the scopes we reviewed.

To keep the price down, even for a Dobsonian, Coulter sacrifices finish and fittings. Don't expect finely crafted hardwood or even low-grade plywood — the Coulter

mounts are made of painted chipboard. A finderscope is optional — we feel the Telrad finder Coulter offers is an essential extra.

The highly portable mount was solid; vibrations damped out in 1 to 2 seconds. We did find the 43-pound 8-inch to be top heavy. Even when aimed up at 45° the scope would slowly sink, causing objects to drift out the bottom of the field. The problem would be worse with a heavy eyepiece or finderscope attached. Some small counterweights at the back end of the scope would solve this. Like a wobbly table, the whole scope also tipped slightly whenever the scope was moved in azimuth, due in part to an azimuth motion that was a bit too sticky. But on the whole, the mount moved very smoothly.

The optics were a pleasant surprise. We rated the Odyssey 8 a good B-. In-focus and out-of-focus stars revealed mild spherical aberration and surface roughness, and some slight astigmatism. But the minor levels of aberration did not prevent satisfying views of Saturn — Cassini's division was visible all the way around the rings and the belts on the planet were plainly visible.

MAKING THE GRADE

We perform the optical tests by examining star images at high power both in-focus and out-of-focus, a sensitive method of detecting even minor aberrations. (See "Test Drive Your Telescope" by Dick Suiter in the May 1990 *ASTRONOMY*.) We use both an artificial star indoors and real stars in typical Wisconsin skies. As a check, star images are also examined using a Ronchi grating, a test that will show major figuring errors in the optics. We also examine planetary images for critical detail and contrast. We then rate the optics on an A through E scale:

A = Excellent. Clean Airy disk on stars in focus and nearly identical diffraction patterns either side of focus.

B = Very Good. Distinct Airy disk in focus but extrafocal diffraction patterns exhibit some signs of mild spherical aberration or zonal errors.

C = Acceptable in low-cost telescopes. Disturbed or fuzzy Airy disk in focus and evidence for strong spherical aberration or mild astigmatism.

D = Poor. Strong astigmatism or other aberrations severe enough to make it impossible to form stellar Airy disk or sharp planet image. Likely defective.

E = Reject. Optics suffer from high level of several aberrations. Images are blurs with no semblance of focus on stars or planets.

The "Star" rating is a summary of the overall optical and mechanical quality, with ☆☆☆☆☆ being excellent.

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Eclipse at Sundown

Start the new year off right by seeing a spectacular sunset eclipse along the coast of southern California.

by Richard Talcott

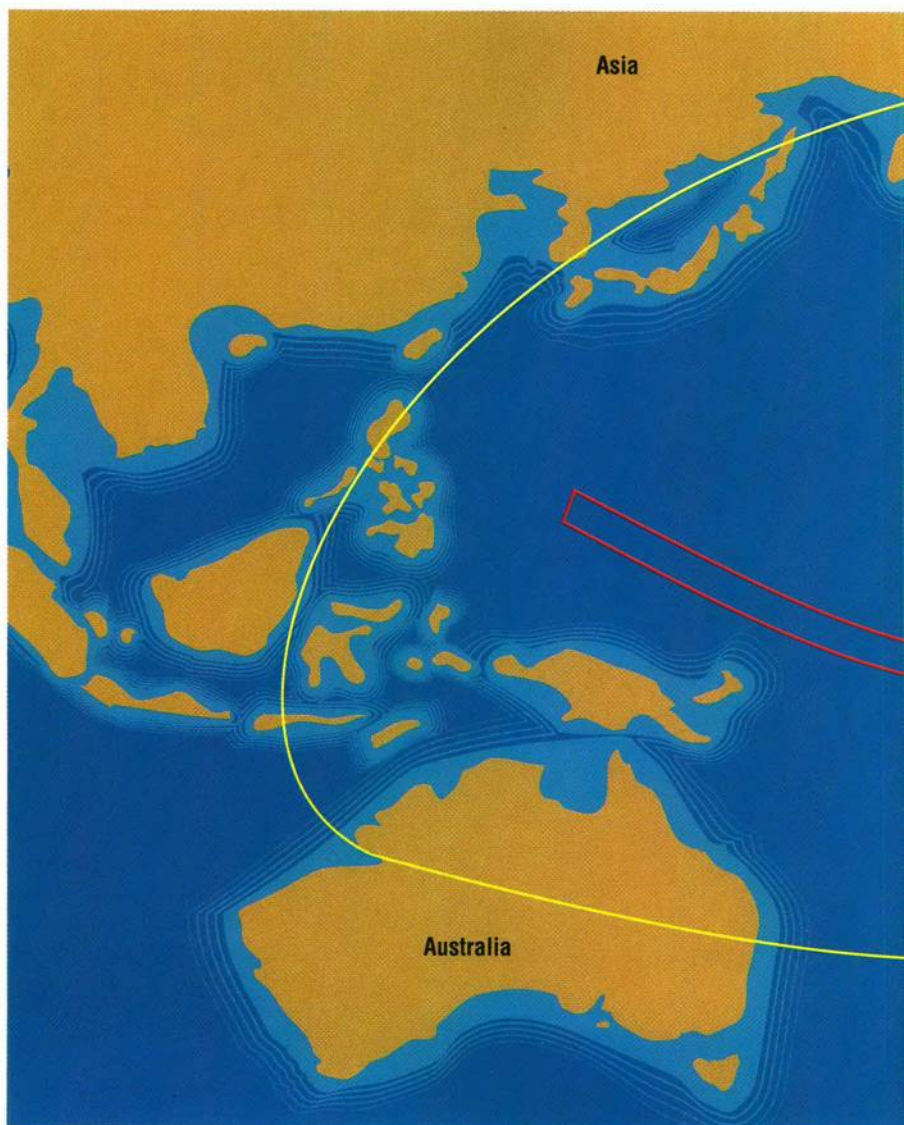
Eclipse chasers from around the globe congregated in Hawaii and Baja California last July to witness what many experts dubbed the eclipse of the decade. Now many of these same people are gearing up for the Moon shadow's next rendezvous with Earth, which comes on January 4-5, 1992.

The reason you haven't heard much about this upcoming eclipse is that the Moon will not completely cover the Sun. Instead of seeing a brilliant diamond ring, fiery red prominences, and a ghostly white corona, eclipse watchers will be treated to a thin ring of sunlight completely encircling the Moon's black disk. And for observers in parts of southern California, this eclipse brings a touch of added drama — the Sun will set into the Pacific Ocean right at the moment of maximum eclipse!

Ring around the Moon

But there's no getting around it — maximum for this eclipse is a far cry from that of last July's eclipse. On January 4-5, the Moon appears noticeably smaller than it did on July 11 and the Sun appears slightly larger. Thus the Moon cannot completely cover the disk of the Sun, leaving a visible ring of sunlight, or annulus, from which the term annular eclipse comes.

The Moon's shadow first touches Earth in the western Pacific several hundred miles east of the Philippines. The time is sunrise, and the calendar says January 5. The shadow then heads southeast over the Pacific Ocean, crossing some islands in both the Caroline Island and Gilbert Island groups. Unfortunately, these regions of the tropical Pacific typically have heavy cloud cover and frequent rains at this time of year — not the best weather for eclipse viewing.

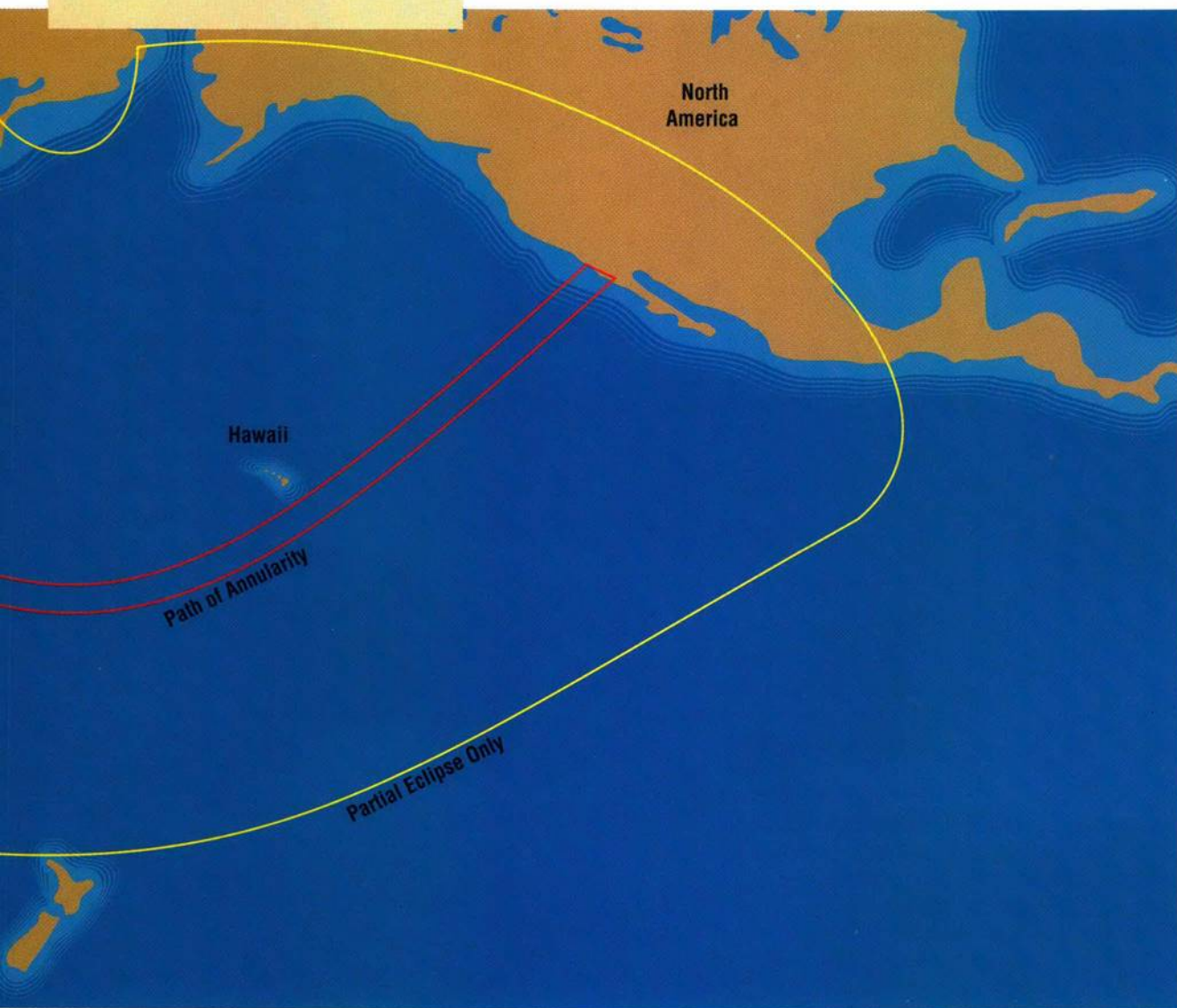


The Moon's shadow races south and east until it straddles the equator, where it crosses the International Date Line. The calendar moves back one day and the eclipse "continues" on the afternoon of January 4. The

point of greatest eclipse occurs just across the Date Line, at longitude 172° west on the equator. There the annular phase lasts for a long 11 minutes and 36 seconds, 96 percent of the Sun's diameter is blocked by the

A RING OF SUNLIGHT surrounds the totally dark Moon during an annular solar eclipse. Observers in southern California will see the Sun and Moon set in the middle of such an eclipse on the evening of January 4. Photo of the May 30, 1984 annular eclipse by Ed Leikam.

THE PATH OF ANNULARITY traces a long trail across the Pacific Ocean from east of the Philippines to the coast of California. Observers from eastern Asia and northern Australia all the way to western North America will see a partial solar eclipse.



Moon, and 84 percent of the Sun's surface area is hidden from view.

The View from California

From there the path of annularity heads to the northeast across the

eastern Pacific and into the area with the highest likelihood of clouds. The weather prospects don't improve much until the shadow's path approaches southern California as sunset nears on the 4th.

The shadow first passes over four islands off the coast of California — San Nicolas, Santa Barbara, San Clemente, and Santa Catalina. Then the shadow reaches the coast and observers on the mainland from



LOCAL CIRCUMSTANCES

Location	Duration of Annularity	Local Time	Percent Eclipsed
Anaheim, CA	1m55s	---	---
Long Beach, CA.....	3m15s	4:53 p.m.	83%
Los Angeles, CA.....	2m07s	---	---
Malibu, CA.....	3m45s	4:52 p.m.	83%
Palmyra Is.....	9m48s	11:40 a.m.	84%
Pasadena, CA.....	1m26s	---	---
San Clemente Is.....	6m53s	4:53 p.m.	83%
San Diego, CA.....	1m24s	---	---
San Nicolas Is.....	9m39s	4:53 p.m.	83%
Santa Barbara Is.....	7m06s	4:53 p.m.	83%
Santa Catalina Is.....	4m54s	4:53 p.m.	83%
Santa Monica, CA.....	3m01s	4:52 p.m.	83%
Tabiteuea Is.....	10m30s	10:04 a.m.	84%
Thousand Oaks, CA...	3m20s	4:52 p.m.	82%
Tijuana, Mex.....	1m47s	---	---
Yap Is.....	2m35s	7:15 a.m.	82%

The time and the percent of the Sun's area eclipsed are given for maximum eclipse. A dash indicates that the Sun sets before maximum eclipse occurs.

around Malibu south to Ensenada, Mexico, will see the eclipsed Sun sink into the Pacific. The map above shows the path of annularity and a line marking where the Sun sets at maximum eclipse. Observers west of this line will see the Sun set after maximum eclipse occurs, while those east of the line will see the Sun set before maximum eclipse.

Although January is the rainy season in southern California, weather prospects for the eclipse are still quite good. You can count on good visibility at sunset roughly ten days during the month, so your odds are about one in three of having a fine view of the eclipse.

Weather prospects for the off-

shore islands are slightly better than those on the mainland, with San Clemente Island having the best chance for clear weather based on weather statistics compiled over many years. The islands are also deeper in the Moon's shadow than the coast so annularity lasts longer there — 6 minutes and 53 seconds on San Clemente and 9 minutes 39 seconds on San Nicolas, compared with approximately 3 to 4 minutes on the beaches around Malibu, Los Angeles, and Long Beach. Still, from most of these locations more than 90 percent of the Sun's diameter is covered by the Moon and 80 percent of the Sun's area is blocked.

If you opt for an island view of the eclipse, you'll need to plan ahead. Santa Catalina is the only island with scheduled ferry or air service — you have to arrange your own transportation to get to the other islands. You can catch a ferry to Santa Catalina from Long Beach, San Pedro, or Newport Beach, but they run only during daylight hours so you'll need to stay on the island overnight. And the ferries dock in Avalon on the east coast of the island, meaning you'll need to hike or bike to the other side to view the setting Sun. If you plan to take this route, make reservations about a month before the eclipse.

After the Sun disappears into the ocean, be sure to watch for the unusual twilight conditions. With the Sun eclipsed as it sets, twilight will come on much faster and be much darker than normal, at least early on. But as the Moon uncovers more of the Sun (all this is happening below the horizon, of course), the western sky should grow slightly brighter before normal twilight sets in. Will you be able to detect this changing pattern? It's a good question. Seeking the answer will make for a nice finish to a truly spectacular sunset. □

Build a Bino-Chair

For less than \$75, this observing chair will bring fun and satisfaction to your binocular observing

by R. Clark Lewis

Wobble! Wobble! I have never had much luck holding my binoculars steady while observing. It doesn't matter whether I try to prop my elbows, lie on my back, or hold the binoculars against something solid. Mounting the binoculars on a camera tripod has also proven unsatisfactory because I dislike standing for a long time and besides, my neck gets stiff. The solution to my woes was to build a binocular observing chair.

The Bino-chair is portable and easy to use, and can adjust to fit different observers. One person can set up the chair in 10 minutes. There is minimal image shake when you track an object and the eyepiece does not change position relative to your eyes as you sweep the sky. Objects — even fast moving airplanes — are easy to track. I have never had so much fun observing!

Swivel and Turn

Like the azimuth part of an alt-azimuth telescope mount, the base of the Bino-chair lets you turn around in a circle so you can look at any part of the sky. The chair rotates easily by gentle pushes with your feet.

Three parts make up the base: a *lawn chair* rests upon an *azimuth board* while casters on the azimuth board spin along a *ground board* to give the base its swivel action. For a shorter Bino-chair, use a beach chair instead of a lawn chair.

The azimuth and ground boards are square sections of plywood. To mount the casters on the bottom of the azimuth board, draw a large circle leaving about 1½ inches of toe clearance at the edges. For stability, place the fixed-wheel casters evenly around the circle, with two of the three casters toward what will be the back edge of the board. Attach

the casters so the wheels are aligned along the circle rather than along the radius.

Affix a long carriage bolt to the ground board so it passes through the centers of both boards. Lightly secure the azimuth board with a washer and a wing nut so the assembly rotates easily.

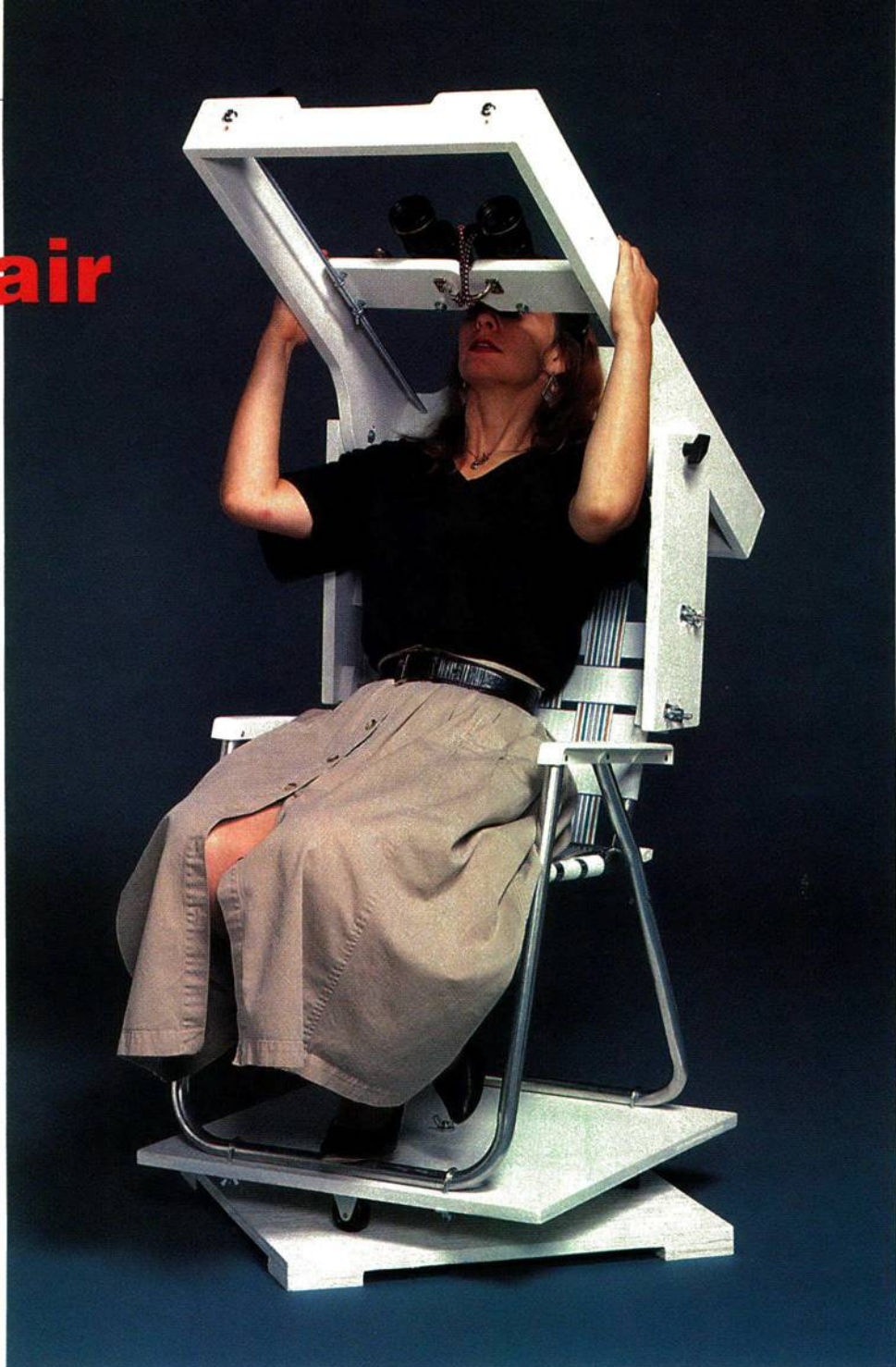
Place the back leg of the lawn chair along the back edge of the azimuth board and attach the chair to the board with four U-bolts. Use wing nuts for the front U-bolts so they may be removed when you

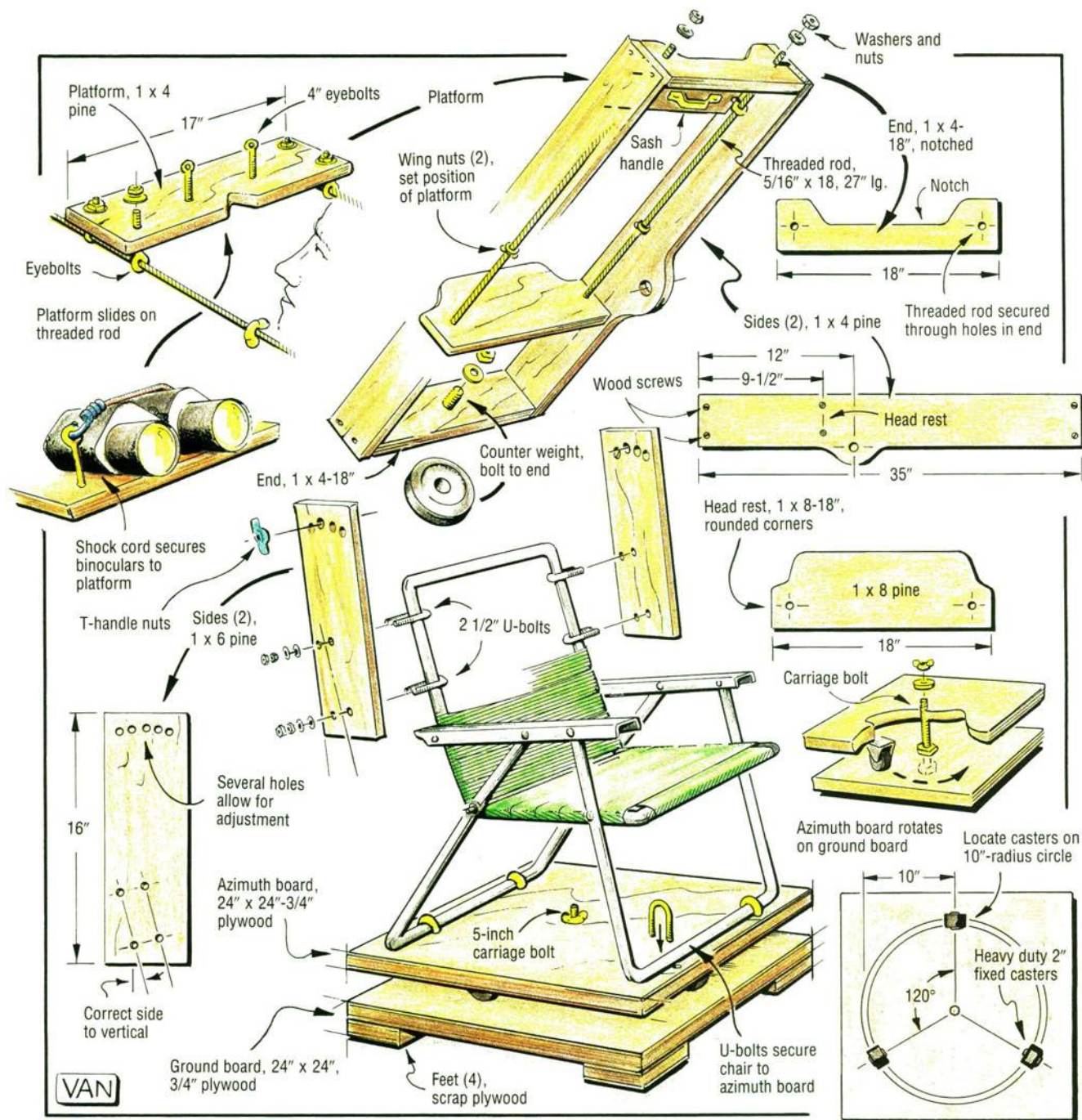
AN ORDINARY LAWN CHAIR becomes an alt-azimuth mount for your binoculars.

fold the chair for transportation. Removal will be easier if you rock the bit back and forth when you drill the inboard holes.

Fitting the Bino-chair to You

For the binocular eyepiece always to be in the proper position, the altitude axis of the Bino-chair must be aligned with the pivot point of your neck. Locate where your





neck pivots; it probably will be just below the ear.

To build your chair, you'll need three measurements. The most critical is the distance from the chair's seat to your pivot point. You also need the distances from the pivot point to the back of your head and from the pivot point to the horizontal line going through your eyes. If you expect to have a number of people using this chair, you may wish to find averages for these measurements.

Up and Down

The altitude axis of the Bino-chair

permits the binoculars to swing vertically as you tilt your head backward so the eyepiece position will not change relative to your eyes. There are two main parts to the altitude assembly. A wooden frame holds the binoculars and has a board upon which to rest your head. The frame swings upon two side boards that attach to the back of the lawn chair. Let's make the side boards first.

How long should each side board be? The pivot hole at the top end of the board should line up with your pivot point. You can drill a series of

holes to move the pivot forward and backward to accommodate different observers. You can drill a second set of holes below the first for greater height adjustment.

The altitude boards clamp to the lawn chair with U-bolts and wing nuts. You can cut slots instead of holes for the U-bolts so you can adjust the board for different observers' heights. *Clamping blocks* with a V-shaped groove chiseled in them fit between the altitude board and the tubing of the lawn chair to prevent the board from twisting. When you transport the chair, loosen



THE BINOCULARS SWING vertically as your head tilts backwards.

After you slide the rods through the holes in the front end-board and through the eyebolts of the binocular platform, don't forget to put a wing nut on each rod before you push the rod through the holes in the headrest. Attach a sash latch on the front end-boards and binocular platform so you can lock the binoculars in place when you get out of the chair.

Test Drive Your Bino-chair

Try out your Bino-chair using airplanes as test objects during the day or the Moon and planets at night. Place the base on level ground and unfold and secure the chair. Reset the position of the altitude boards (a gauge block makes this easy) and attach the frame with bolts. Insert the bolt from the inside of the frame — be sure a nylon washer goes between the frame and altitude boards — and clamp each side with a T-handle. With some practice, set-up can be done by one person.

After checking that the T-handles are securely clamped, put on the counterweights (about 5 pounds) and attach your binoculars with the shock cord. You are ready to try out your Bino-chair!

Slide the binocular platform forward and lift the frame until you can easily sit down. With your head against the headrest, slide the binoculars toward you until they are in a comfortable viewing position. Adjust the wing nuts on the threaded rods until the binoculars stay in this position.

Move between objects by swiveling the base and pushing (or pulling) the sidepieces of the frame. If the frame slips when you let go, tighten the T-handles. (If the frame continues to slip, change the amount of counterweight used.)

Fixing and Fussing

If your "test drive" goes like mine did, your Bino-chair will need some adjustments. You may need to change the positions of the pivot holes. Or the front end-board may need to be trimmed to avoid vignetting the lenses. But once you fine-tune your Bino-chair, I'm sure you will find yourself observing with binoculars more often. □

R. Clark Lewis is a member of the Astronomy Section of the Rochester Academy of Science.

the wing nuts (do not remove!) and rotate the altitude boards toward the back before you fold the chair.

Holding Your Binoculars

The frame provides a headrest, a means to hold your binoculars, and a counterweight so the frame will move easily up and down. The binoculars slide forward upon threaded rods to permit you to get into the chair. These rods are enclosed within the frame so they are more rigid and pose less of a safety hazard when you walk around the chair.

Six boards make up the frame: a headrest, a sliding binocular platform, two sidepieces, and two end-boards — a front end-board and a back end-board (the counterweight board). The sidepieces contain the pivot hole for joining the frame to the altitude boards while the headrest and front end-board have holes for the threaded rods.

The end boards are made from 1x4 pine to keep the frame light. Shape the sidepieces and headrest from 1x8 pine so you can properly locate the pivot point and the headrest can be made comfortably large. The width of the frame is determined from the spacing between your altitude boards. Be sure you allow for the nylon washers that go between the frame and altitude boards.

Align the bottom edges of the front end-board and headrest and drill the holes for the rods through both boards simultaneously. The holes should be about $1\frac{3}{8}$ inches

from the top edge of the front end-board and about 15 inches apart.

The length of the sidepieces is not critical, but 30 to 36 inches should be long enough so you can slide the binoculars out of the way when getting into the chair. The top of the sidepiece corresponds to your line of sight through the binoculars. Drill the pivot holes simultaneously through both sidepieces about 14 inches from the back end and the distance between your eyes and your neck's pivot point down from the top. You may wish to drill two additional holes, one above and one below this pivot hole to provide some additional height adjustment.

When you assemble the frame, drill pilot holes through the side boards into the end boards so the pine won't split. The headrest is attached behind the pivot hole the same distance as between your neck's pivot point and the back of your head.

The binocular platform has eyebolts mounted facing downward in each corner so they will slide over the rods. In the center of one edge, cut a large V-shaped notch to provide relief for your nose. Cut a smaller notch in the center of the other edge for the shock cord that holds the binoculars to the board. A sash handle mounted on the bottom of the board and two long eyebolts are the connection points for the shock cord, which holds the binoculars in place. Slide a section of plastic tubing over the threads and mount the eyebolts on each side of the deeper notch.

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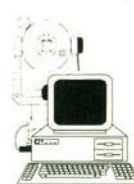
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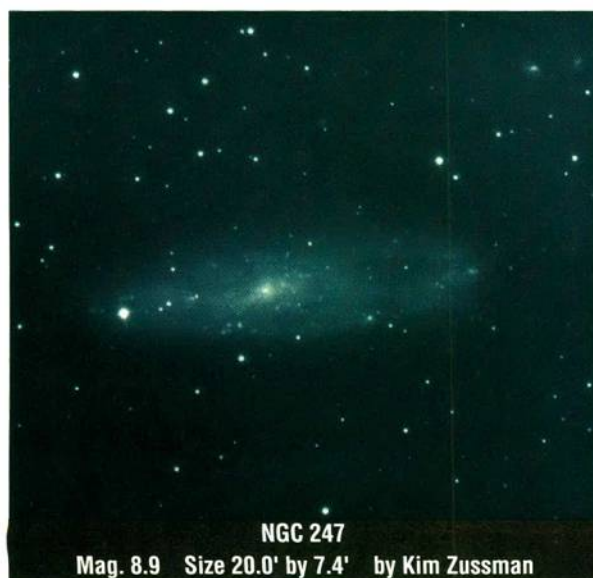
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Observing the Sculptor Group of Galaxies

Discover a little-observed yet bright and detailed collection of spiral galaxies lying near the South Galactic Pole.

by Rod Pommier



Winter is a season that strikes fear into the hearts of deep-sky observers. Rather than visions of sugar-plum fairies, diehard galaxy fans see visions of icicles dancing through their heads, of the warmth and galaxies of spring that still lie a long way off. Yet if you're willing to dress warmly and brave the cold, a spectacular group of galaxies awaits your gaze in the evening winter sky. The Sculptor Group of galaxies includes NGC 55, NGC 253, NGC 300, and NGC 7793 in Sculptor, as well as NGC 247 in Cetus.

NGC 253 is the showpiece galaxy of the Sculptor Group, by far the largest and brightest member of the group. It is probably the easiest spiral galaxy to observe after the great spiral galaxy M31 in Andromeda. Although NGC 253 ranks as one of the great showpieces of the entire sky, it is rarely recognized as such.

NGC 253 is one of the best examples of an S-type galaxy. To find NGC 253, first locate the bright star Alpha Sculptoris. Then move 4.5° northwest, passing the fuzzy glow of globular cluster NGC 288, and you'll come upon NGC 253. In an 8- to 10-inch telescope, the view of NGC 253 is an impressive sight second only to that of M31. NGC 253 appears as a bright, elongated "silver dollar" rich in detail. The galaxy brightens gradually from the edges toward the central region, which contains a brighter, non-stellar core. Mottling is easily seen in the middle portions of the galaxy, where it surrounds the core. The mottling fades as it extends toward the periphery of the galaxy.

In a 12-inch or larger telescope, NGC 253 is stunningly bright. The central region appears distinctly non-stellar. The nuclear region also appears elongated along the major axis of the galaxy. The mottling is much more prominent as the nebulosity extends away from the center: dark lanes can be traced from the region surrounding the nucleus to the very edges of the galaxy. Regardless of the aperture used, NGC 253 is a beautiful sight that leaves an impression etched on your mind.

The next brightest galaxy in the Sculptor cloud is **NGC 55**, a large system seen nearly edge-on from our vantage point in the Milky Way. In contrast to other classic edge-on galaxies (such as M104, NGC 4565, NGC 891, or NGC 5907), NGC 55 exhibits neither a prominent central bulge nor an equatorial dust lane. Instead, large-scale photographs reveal large, irregular dust clouds and emission nebulae scattered across



NGC 253

Mag. 7.1 Size 25.1' by 7.4' by Scott Hicks

the galaxy and a bright central mass displaced toward one end of the galaxy. For these reasons, NGC 55 is classified as an irregular galaxy and is thought to resemble the Large Magellanic Cloud in its structure. Gérard de Vaucouleurs believes the system to be a distorted, old, barred spiral galaxy with S-shaped spiral arms that are viewed nearly edge-on. The galaxy has a mass of about 46 billion solar masses and a luminosity of about 6 billion suns.

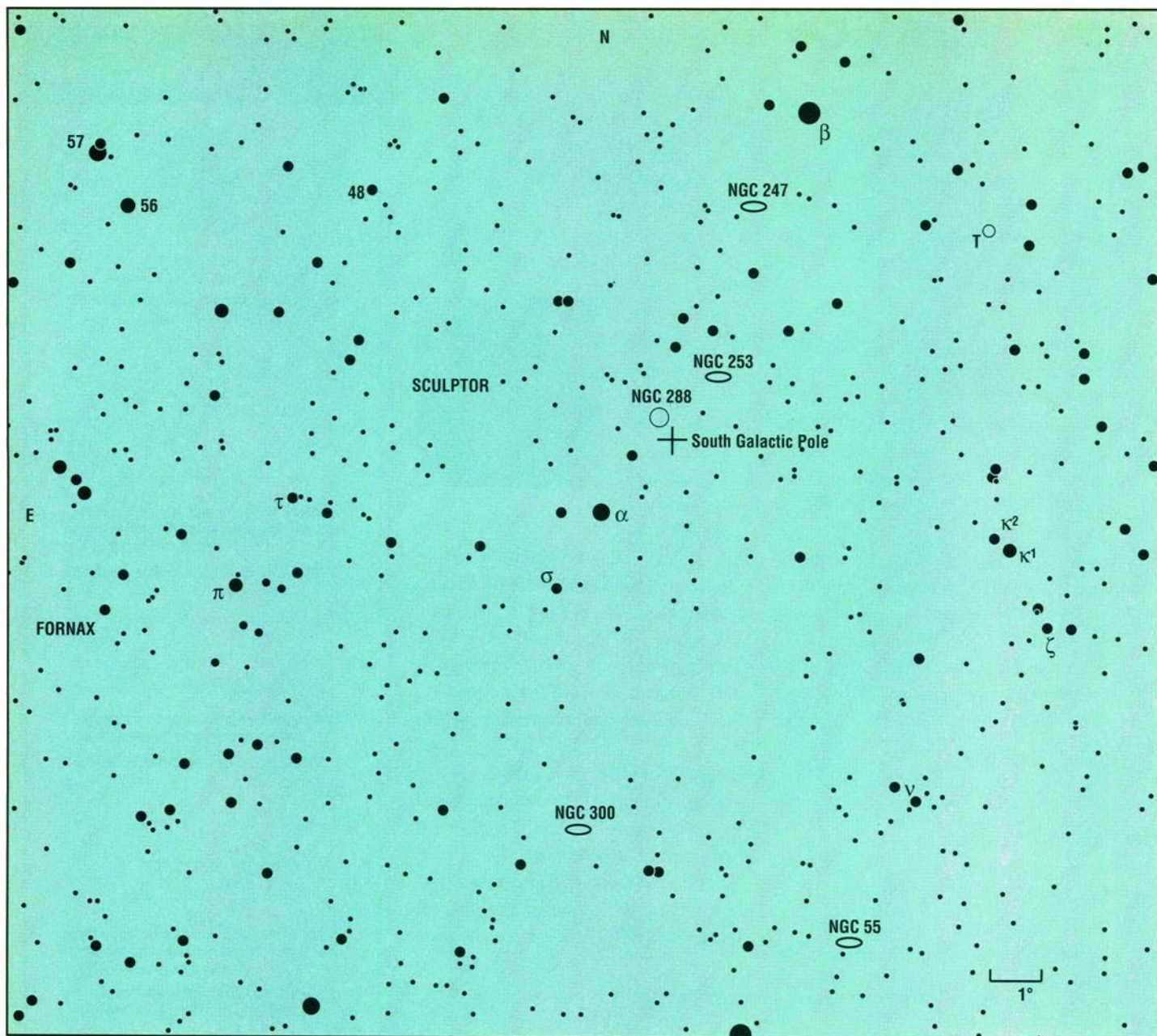
To locate NGC 55, first locate the 3rd-magnitude star Ankaa (Alpha Phoenicis). Many amateur astronomers in northern latitudes are unfamiliar with this star because it lies in the southern constellation Phoenix. However, Ankaa lies at the same declination as the southernmost stars in the tail of Scorpius, with which most amateur astronomers are very familiar. Therefore, be assured that if you can trace the tail of the scorpion along the southern horizon in summer, you'll also find Ankaa in winter. From there, move your scope 3° north to an east-west row of three evenly spaced 7th-magnitude stars. This row

points directly west to NGC 55. From the westernmost star, proceed west about the same width as the row of three stars to arrive at NGC 55.

In an 8-inch telescope, NGC 55 appears large and elongated. Several of the features notable in photographs of this galaxy can be discerned. There is a bright nucleus which is clearly off-center, being displaced toward the northeast end of the galaxy. Motting is evident in the central area of the galaxy.

Nearby lies the challenging galaxy **NGC 300**. This galaxy is interesting because it bears a striking resemblance to M33 in Triangulum. Both are visually large, class Sc spiral galaxies with compact nuclei and well-formed spiral arms that can be resolved into bright clumps of blue stars and emission nebulae on large-scale photographs. NGC 300 is inclined approximately 42° to our line of sight, similar to the 55° of inclination exhibited by M33. The distance to NGC 300 is approximately 6 million light-years. It has a mass of about 25 billion solar masses.

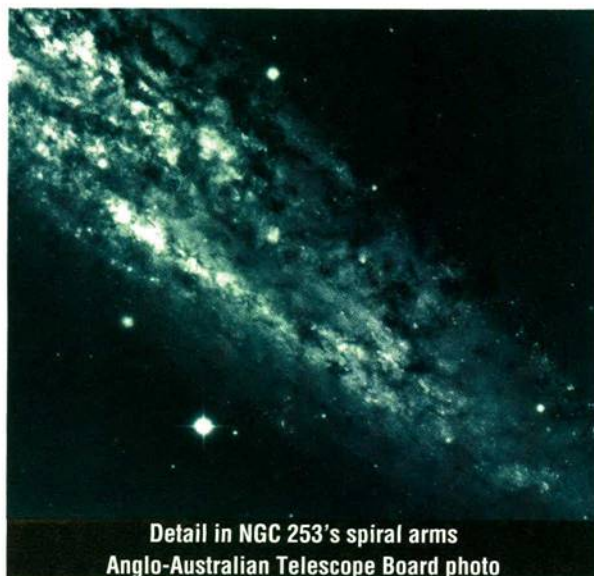
To locate NGC 300, start again with Ankaa.

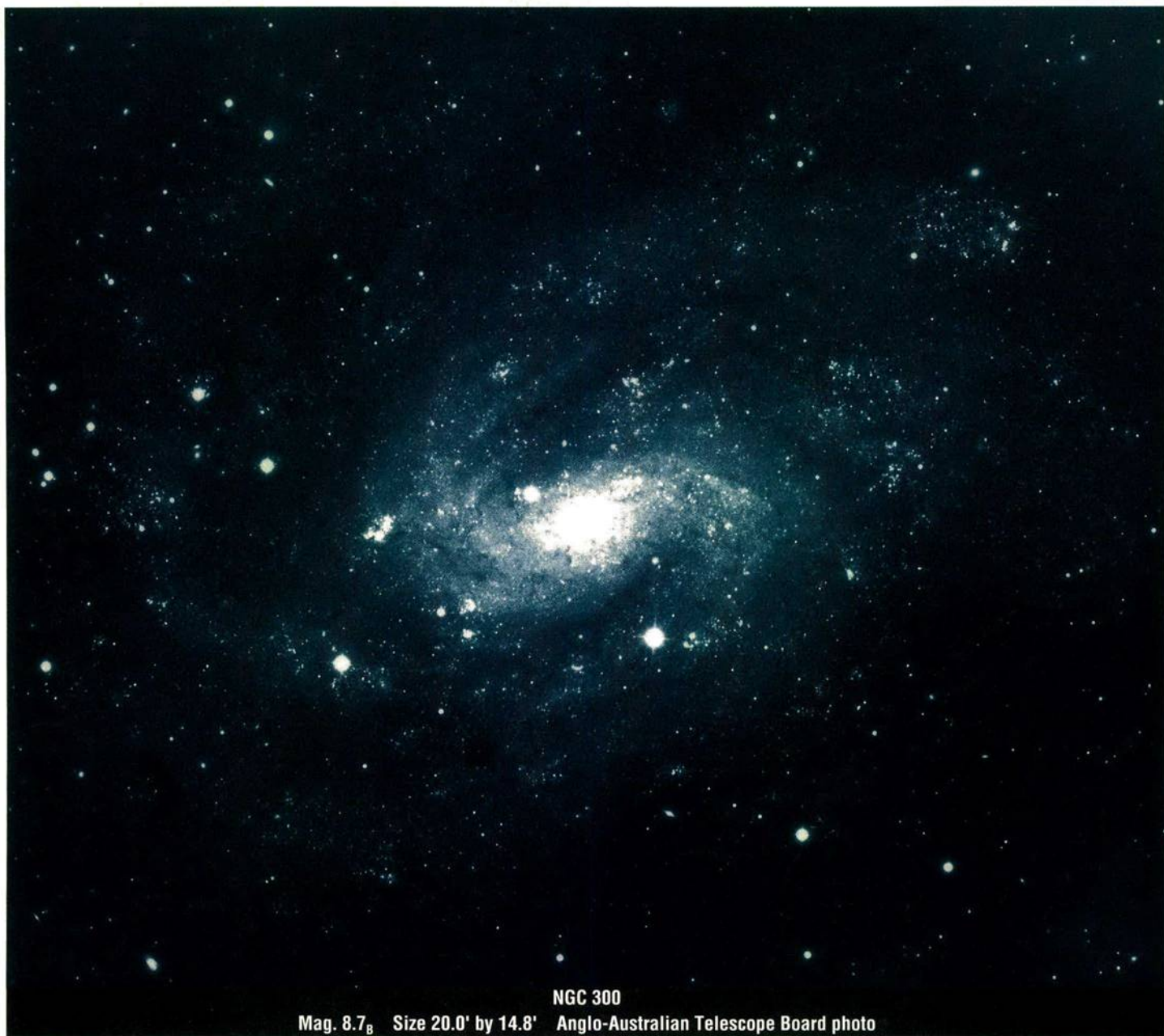


Bright Galaxies in Sculptor

Object	R.A. (2000.0)	Dec.	Mag.	Size
NGC 55	0h14.9m	-39°11'	8.2 _B	32.4' by 6.5'
NGC 247	0h47.1m	-20°46'	8.9	20.0' by 7.4'
NGC 253	0h47.6m	-25°17'	7.1	25.1' by 7.4'
NGC 300	0h54.9m	-37°41'	8.7 _B	20.0' by 14.8'

Object: Designation in NGC catalog. **R.A. and Dec.:** Right ascension and declination in equinox 2000.0. **Mag.:** V magnitude of galaxy; subscript B denotes blue magnitude. **Size:** Diameter in arcminutes.





NGC 300

Mag. 8.7_B Size 20.0' by 14.8' Anglo-Australian Telescope Board photo

Move the telescope 5° northwest to a wide double star, Lambda¹ and Lambda² Sculptoris. A chain of 5th- to 8th-magnitude stars will lead you directly from Ankaa to Lambda¹ and Lambda². From Lambda², move the telescope ¾ of a degree north. Next, wait 11 minutes without moving the telescope (or using a clock drive), and Earth's rotation will carry NGC 300 into the center of the field of view. This technique is known as the star drift method. Use a low-power, wide-field eyepiece while waiting for the galaxy to appear and be sure to keep a very sharp eye out for it.

Through an 8- to 10-inch telescope, NGC 300 is a fairly difficult object because of low surface brightness. It has a bright, star-like nucleus which is much brighter than the nucleus of M33. The nucleus is surrounded by a large, tenuous, shell of nebulosity. This shell is very difficult to observe if there is much haze on the horizon. Therefore, a crystal clear night is essential to fully appreciate the extent of this galaxy. Averted vision helps to make the nebulous shell stand out, but no spiral arms or dust lanes can be seen.

The galaxy **NGC 247** lies in the constellation Cetus, yet belongs to the Sculptor Group of galaxies. It shares many characteristics with the previous two galaxies. Visually, it is like NGC 300 in that it is a large galaxy with a low surface brightness. Structurally, it is like NGC 55 in that it is ill-defined. Areas of light and dark, similar to those of NGC 55, are seen on large-scale photographs, but no definite spiral arms can be traced.

These galaxies are a mere sampling of what the Sculptor region has to offer. To explore some of the many fainter galaxies surrounding these objects, sweep the region with a low-power eyepiece and you'll surely come upon many faint smudges of light. As you log the details of each object, remember that each is an island universe consisting of billions of stars. And don't stay out too long, either — it's winter, after all! □

Rod Pommier is a physician employed at the Memorial Sloan-Kettering Cancer Center in New York City.

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A STRONG SHOW OF PERSEIDS

August's Perseid meteor shower, historically one of the best shows of the year but recently rather poor, may be undergoing a renaissance. Brian Marsden in his International Astronomical Union (IAU) Circular No. 5330 (for August 28, 1991), states that "David Levy and Peter Jedicke report that their observations from Springfield, Vermont, through clouds, showed what was obviously a rather intense display of Perseids [on August 12.3 universal time], with 15 meteors, one as bright as magnitude -8 , being noticed in an interval of 40 minutes."

Levy and Jedicke were two of the hundreds of observers at the 1991 Stellafane convention to observe a surprisingly active year for the Perseids. And reports came streaming in from other locations, all pointing to increased activity.

From Tucson, Arizona, Tim Hunter relates that on the morning of the 13th he drove to his dark-sky observatory to watch the shower. "From 2:00 to 3:00 a.m., I saw 92 meteors, about 90 percent of those being Perseids. Two-thirds of them were bright, approximately 1st or 2nd magnitude, and many left trails visible for 1 or 2 seconds. Between 3:00 and 4:00 a.m. I saw 74 meteors, after which I began to pack up and head back to town. As I got the truck ready the activity picked up, and I saw at least two meteors per minute."

Michael Boschat observed the Perseids from outside Halifax, Nova Scotia. "On the night of August 12/13, I saw a grand total of 95 meteors over three hours," says Boschat. "The two brightest were a -6 magnitude fireball that had a orangy glow and left a trail that lasted for 2 seconds. The second, also glowing at -6 magnitude, was bluish and seemed to light up the whole sky."

From near Glen Ullin, North Dakota, Jay J. Brausch recorded that "meteors averaged magnitude 2.5 to 3.0. A -3.5 magnitude Perseid observed on the 13th left a glowing dust trail that persisted for nearly 10 seconds in growing twilight. Many meteors were orange, but this coloration was missing in the fainter objects."

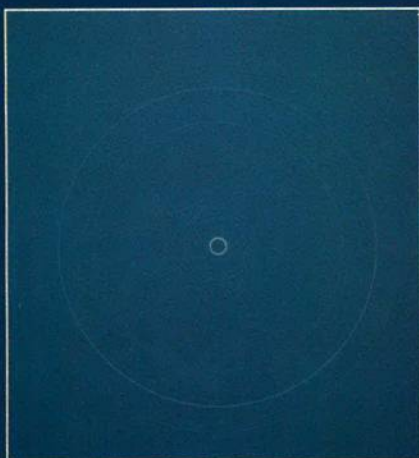
Astronomers at the Kiso Observatory in Japan recorded a corrected zenithal hourly rate of more than 400 meteors during the peak of activity on August



BRIGHT METEORS ABOUNDED during the most active Perseid shower in recent years. Photo of a Perseid over the Grand Canyon on August 13, 1991 (top), by Debbie Kutner; photo of a Perseid blazing past the Andromeda Galaxy on August 12 by David R. Scherping (above left); closeup of a typical Perseid on August 12 by Jonathan Sabin (above right).

12. Marsden points out in IAU Circular that comet P/Swift-Tuttle, known to be the source of the Perseid meteor stream, may be identified with an an-

cient comet that is returning in 1992. If true, this may account for what appears to be dramatically increased Perseid activity. — David J. Eicher



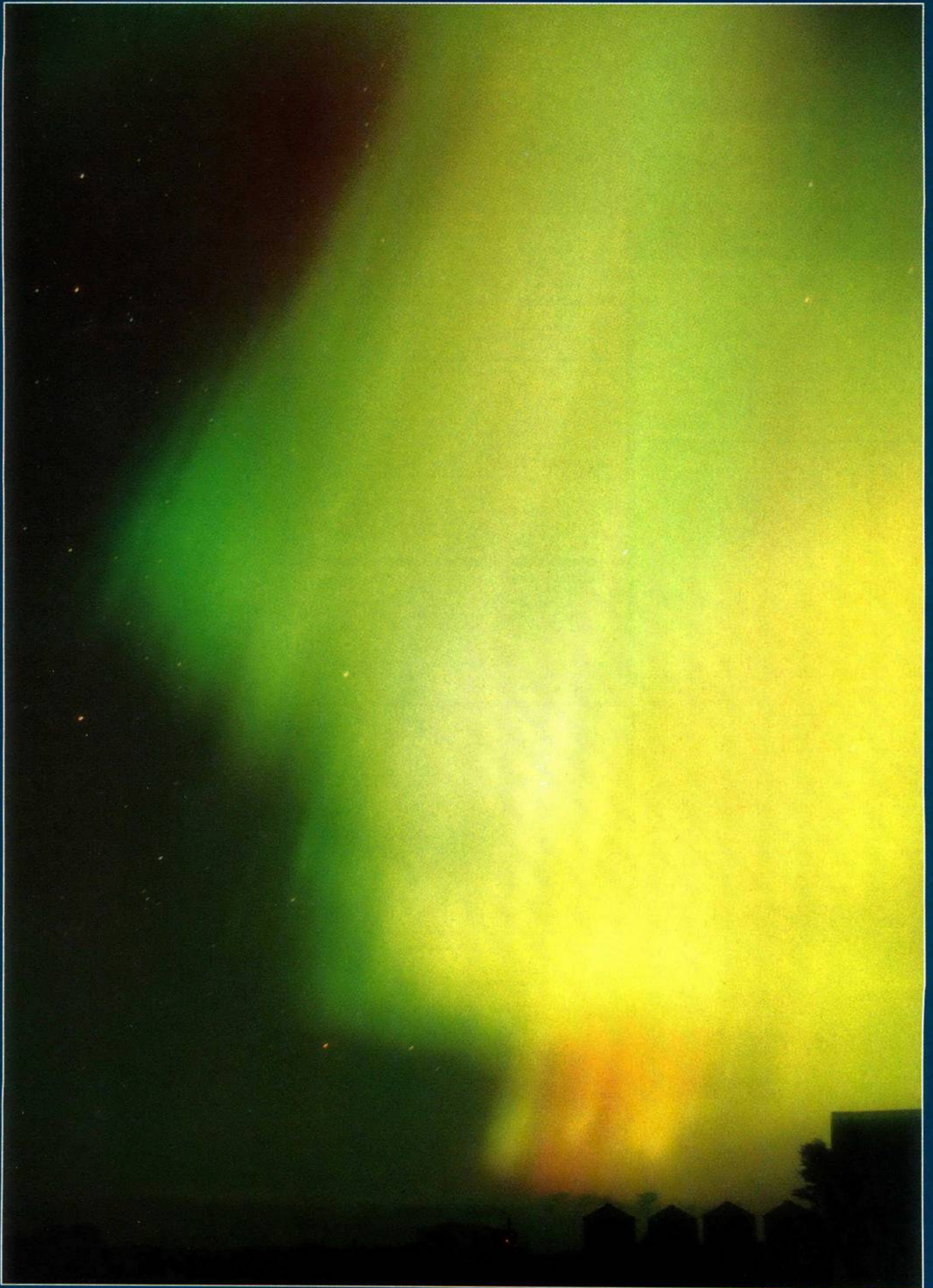
BRILLIANT AURORAE LIGHT UP THE SKY

Jay J. Brausch's photo of an aurora towering over Glen Ullin, North Dakota (opposite page), wins this month's \$100 "Best Astrophoto" award. Brausch made the photo on July 9, 1991. The wide-angle nature of the shot and huge extent of the aurora can be seen by looking at the dwarfed grain storehouses at lower right.

Did you ever wonder what an all-day exposure of the North Celestial Pole would look like? Ron Lee has provided the answer, having sent an exposure made in Greenland in December 1979 (above left). It is a 24-hour exposure on Kodachrome 64 made with a 28mm lens at f/16.

Comets continue to captivate observers and astrophotographers. Comet Levy 1991q was photographed extensively last summer. Michael Stecker captured Comet Levy on June 22 (left center). Jeffrey Jones' photo shows the comet's appearance on August 11 (above center). Gerald Rhe-mann of Vienna, Austria, photographed Comet P/Hartley 2 on August 8 (above right).

The Galilean satellites of Jupiter constantly dance about the giant planet, periodically causing eclipses and transits. David Roles' series of three images (left) of the Jovian system shows the May 29, 1991 event in which Gany-mede eclipsed Io and diminished the latter's light by 98 percent. Io is the second satellite from the left, bright in the first frame, gone in the second, and partially obscured in the third.

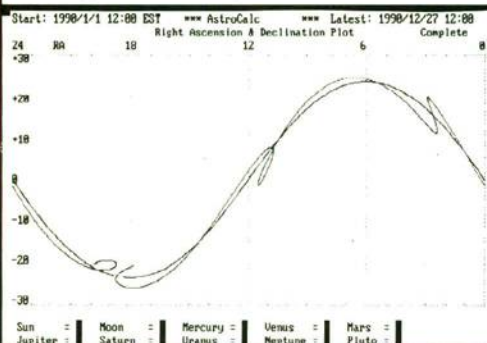


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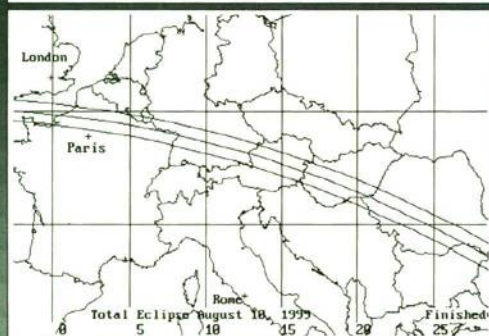
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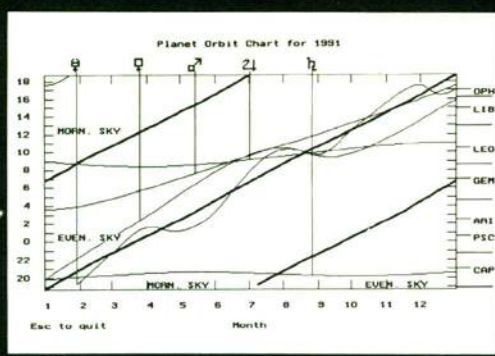


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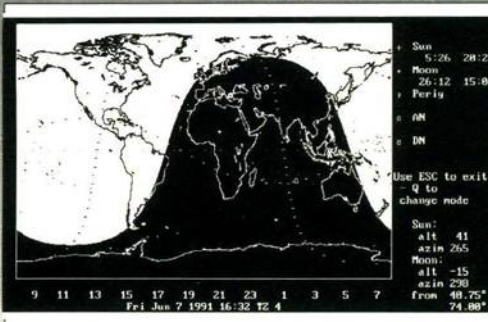
□ MoonTimes - Similar to SunTimes but gives data for the Moon. Includes rise/set times, phase of the moon and the azimuth (or horizon position) for each rise and set time. IBM. **\$29.95**

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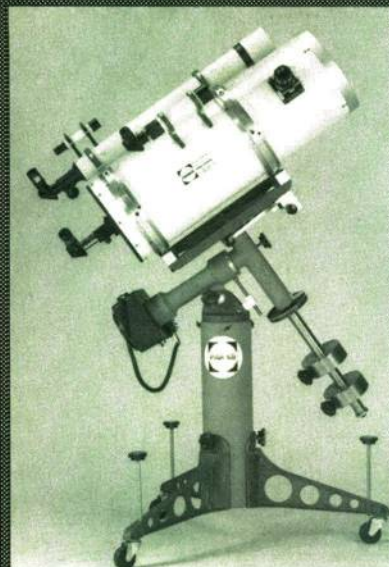
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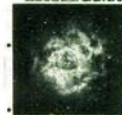
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Astronomy Books

A GUIDE TO URBAN ASTRONOMY?

The Urban Astronomer, by Gregory L. Matloff, (John Wiley & Sons, 1991), ISBN 0-471-53142-1, 224 pages, hardcover, acid-free paper, \$24.95.

The Urban Astronomer was one of those books I just had to have. I was sure that a book so titled would tell me all about such things as deep-sky filters and how to spot nebulae under adverse conditions. It might even help me design an observing shelter appropriate for my San Antonio backyard in an urban area plagued by both burglars and security lights.

Matloff teaches at Long Island University and directs an urban astronomy program for the New York City Department of Parks and Recreation, so he should be well-acquainted with the problems of urban astronomy. Indeed, his book appears to be a spin-off from that program — my impression is that it was written for urban area residents who have recently become interested in astronomy. The writing is pleasantly warm, and each chapter begins with a short quote from a poet such as Walt Whitman, Robert Frost, or Alexander Pope.

Most of the artwork is attractive, but I wish that the four photos in the gallery section had either been left out or printed better. As it is, the muddy, washed-out look of the photographs seems only to emphasize the bleakness of the typical urban sky.

In content, the author covers ground typically dealt with in more detail in introductory astronomy texts. I felt that this created a problem in focus: the book is far too basic for advanced amateurs, but beginners will probably find it isn't detailed enough. There is relatively little solid information to get beginners truly squared away with a topic.

In addition, common terms are used inconsistently. For example, the author substitutes spotter scope for finder scope from time to time. Beginners often find this sort of thing disorienting. And on occasion, statements of fact are either wrong or misleading: for example, "no meteor has ever reached the ground" (page 151). I understand what the author intends — that the fluffy bits of dust which make meteors in the night sky and the meteorites in the museums are different — but I'm not at all sure that the point will be clear to beginners!

The book has some good features. Matloff offers a set of almost 40 activities appropriate for amateur astronomers who do not have access to those dark skies of which we all dream. In addition, he provides a useful listing of various astronomical resources available to amateurs, and has given some good advice on how to tap into those resources.

But does *The Urban Astronomer* offer enough beginner-value that I'd recommend my astronomy students buy it? I don't think so. Will experienced amateurs find it indispensable? I doubt it. Finally, did the book answer my urban astronomy questions? Sorry, but it didn't. —Tom Mote

Observing

1992 Yearbook of Astronomy, edited by Patrick Moore, (W. W. Norton, 1991), ISBN 0-393-03078-4, 224 pages, hardcover, \$22.95.

This is the 30th volume in an annual series. The unvarying format features a detailed month-by-month description of sky events (with simple sky charts) and a half-dozen or so articles on assorted astronomical topics. This year's articles include "A Guide to Stellar Photography" by John Fletcher, "The Planets of Interstellar Space" by Paul Murdin, and "Active and Adaptive Optics" by Ron Maddison.

Workbook for Astronomical Photoelectric Photometry, by Paul C. Schmidtke and Jeffrey L. Hopkins, (HPO DeskTop Publishing, 1990), ISBN 0-9628592-1-4, 196 pages, paperback, \$19.95.

Schmidtke and Hopkins provide a detailed introduction to photoelectric photometry for dedicated amateur astronomers or students planning to become astronomers. The book assumes the reader is comfortable with equations.

Cosmology

Ancient Light, by Alan Lightman, (Harvard University Press, 1991), ISBN 0-674-03362-0, 170 pages, sewn binding, acid-free paper, hardcover, \$18.95.

This book about cosmology is aimed at the interested lay reader and is written in a direct, yet easy style. It begins with the ancient world and finishes with

today's speculations and theories about the shape and size of the universe.

The Origins of the Universe, by Malcolm S. Longair, (Cambridge University Press, 1991), ISBN 0-521-41140-8, 128 pages, hardcover, \$34.50.

Longair gave five popular talks on astronomy at the Royal Institution of London during the 1990 Christmas season. The talks concerned the bigger objects of the universe — galaxies, quasars, and the large-scale structure of the cosmos.

General Astronomy

Chandra, by Kameshwar C. Wali, (University of Chicago Press, 1991), 341 pages, acid-free paper, sewn binding, hardcover, \$29.95.

Subrahmanyan Chandrasekhar — "Chandra" — is reckoned by many as the greatest living astrophysicist. This is a detailed and readable biography of a great scientist and an interesting man whose career spans most of this century.

Wanderers in Space, by Kenneth R. Lang and Charles A. Whitney, (Cambridge University Press, 1991), ISBN 0-521-24976-7, 316 pages, sewn binding, hardcover, \$54.50, paperback, \$24.95.

Wanderers in Space is a good, largely non-technical guide to the "new" solar system that has emerged from the last few decades of missions to the Moon and planets.

Church, State, and Astronomy in Ireland, by J. A. Bennett, (Armagh Observatory, 1990), ISBN 0-9504478-1-1, 277 pages, sewn binding, paperback, no price given.

In the course of providing a history of Armagh Observatory, which celebrated its bicentennial in 1990, Bennett also gives a survey of astronomical work done in Ireland.

Under the Southern Cross, by Ragbir Bhathal and Graeme White, (Kangaroo Press, 1991), ISBN 0-86417-376-8, 96 pages, sewn binding, \$26.95.

Informally written and heavily illustrated, *Under the Southern Cross* is a history of astronomy in Australia. Starting with Aboriginal cosmology, the story runs down to the large radio and optical telescopes of today. Several appendices give addresses of observatories, museums, planetariums, places of historical or archaeoastronomical interest, and amateur and professional astronomical societies. □

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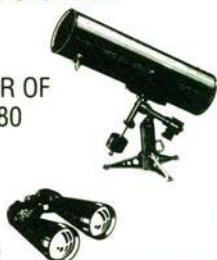
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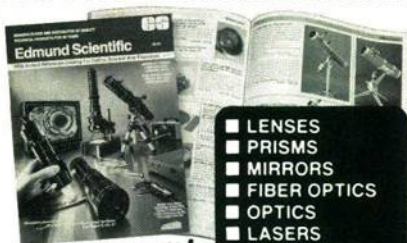
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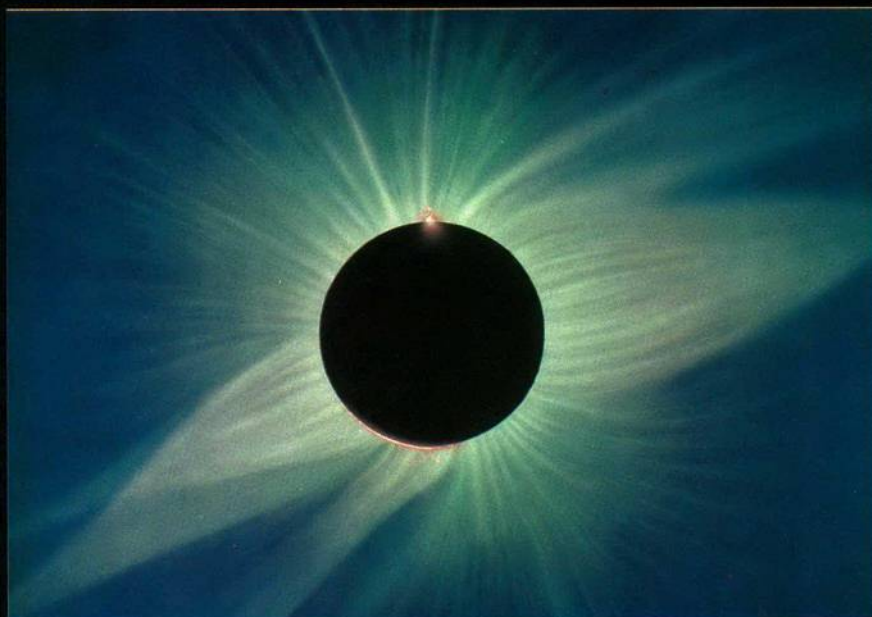
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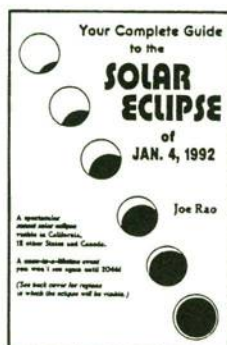


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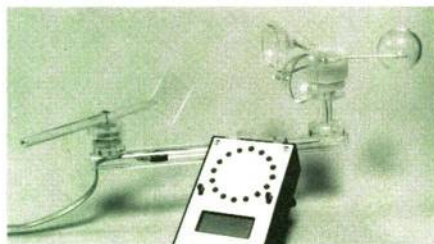
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ZAPPING THE DEW

Orion Dew Zapper, Orion Telescope Center, 2450 17th Avenue, P.O. Box 1158-A, Santa Cruz, CA 95061. AC and DC models for 8-inch Schmidt-Cassegrains: \$44.95 (same price for 10-inch AC and DC models).

You've seen ads for The Clapper? Well this is the Zapper. It's the type of low-cost accessory whose ads and catalog listings you always see but tend to skip over. You think, "What a gimmick. I don't need one of those. Besides, it probably doesn't work." Well, I found otherwise. The Dew Zapper really does work. And if you ever encounter dew during your observing sessions, you really do need one.

The Dew Zapper from the Orion Telescope Center is a heated coil that wraps around the front of a Schmidt-Cassegrain telescope. It keeps the corrector plate just warm enough to ward off an onslaught of dew. Any telescope can be hit by dew but Schmidt-Cassegrains are especially susceptible. Their large exposed corrector plates provide an ideal surface for dew to condense on.

To keep off dew, you can use a dewcap but these accessories only delay the formation of dew. Once dew forms, occasional blasts of warm air from hair dryer guns will clear the optics. But the best way to keep dew from forming in the first place is to apply a constant but low level of heat to the optics. That is the principle behind the Dew Zapper. Orion offers two versions: a model that operates from 110 volts AC, and one that plugs into a car's lighter socket and operates from 12 volts DC. I tested the DC model, the one most likely to be used in the field.

I tested it on a night with 75 percent humidity and when the temperature had fallen below the dewpoint of 59° Fahrenheit. An hour after being first placed outside, the Schmidt-Cassegrain's corrector plate was heavily dewed up. (I had left the test telescope aimed nearly straight up, a worst case for attracting dew.)

I then cleared the corrector with a quick application of warm air from a hair dryer gun on its lowest setting. I turned on the Dew Zapper and left the telescope aimed straight up. After an hour, with the temperature falling and with no dewcap installed, the corrector plate showed slight dewing around the center area but the edges were clean. Everything else, including the finderscope and the cover of the secondary mirror cell, was dripping

with dew. After another hour with the bare corrector plate aimed up at the sky the entire time, the corrector showed even less dew — it was clean and dry with just a trace of condensation around the secondary mirror cell. What's more, the tube of the telescope itself was dry. The Zapper's heat was warming the corrector and the tube, and yet to the touch the Zapper felt only slightly warm.

Purists may balk at the thought of heating any optics for fear it will affect the figure of the glass and blur star and planet images. However, I found this was not the case with the Zapper and its low level of heating. Besides, I would rather have clear but slightly fuzzy optics than sharp optics made ineffective by a thick coat of moisture.

My only criticisms of the Dew Zapper are with the design. The heated coil is embedded in a plastic strap that is held in place around the telescope by a separate elastic belt. But as you tuck in one end of the Zapper coil, I found that the other end tends to pull out from under the elastic by the weight of the heavy power cord (even the DC model uses heavy gauge wire). A single strap, held in place with Velcro perhaps, would be far more convenient than this two-strap arrangement.

My only other comment is that it would be great to see models offered for other sizes of telescopes such as 3- to 6-inch refractors, as well as an adjustable mini-Zapper for eyepieces, finderscopes, and camera lenses. Despite the fact that just about every telescope user could benefit from anti-dew heaters, few companies offer them, forcing most amateurs to concoct these devices themselves from toaster wire and bits of fabric. I've never cared for accessories that drape my telescope with wires and cords, but when it makes the difference between observing on an otherwise perfect night and not observing (or not photographing), I'll take the tangle of cords.

I recommend the Dew Zapper as an accessory that works very well. It is probably the best \$45 you'll ever spend improving your Schmidt-Cassegrain.

— Alan Dyer

SPECIAL PUBLICATIONS OF INTEREST

The Universe in the Classroom, *Astronomical Society of the Pacific, Teacher's Newsletter*, Dept. N, 390 Ashton Avenue, San Francisco, CA 94112, (415) 337-1100. Free to teachers and librarians in grades 3 to 12 who request it on school stationery.

Many educators may not yet be aware of the *Astronomical Society of the Pacific's* excellent newsletter for teachers. Published quarterly, each free issue contains short non-technical articles on new developments in astronomy, instructions on classroom activities for teaching astronomy, and notices of the best printed and audio-visual resources on astronomical topics. Recent issues covered topics such as the July solar eclipse, the Hubble Space Telescope, astrology, and Moon phase demonstrations. It is designed for educators with little or no experience with astronomy and is a publication highly recommended for all science teachers.

The Practical Observer, 313 Raphael Avenue, Middlesex, NJ 08846-1224, (908) 469-3850. One year subscription (four issues): \$12 in the U.S. and \$15 outside the U.S.

Over the last two years this small 20-page quarterly has specialized in publishing "how-to" articles about the practical nuts and bolts of amateur observing. It reviews techniques to help amateur observers get the most out of their backyard sessions. The publication also runs frequent editorial and opinion pieces about issues of interest to amateur astronomers. Edited by Gordon Bond, *The Practical Observer* is an excellent effort and a publication to which ardent amateurs may want to subscribe.

SOFTWARE UPDATE

The Genesis Project, Version 3.0a, Lewis-Michaels Engineering, 48 Delemere Boulevard, Fairport, N.Y. 14450-0248, (716) 425-3470. Requires IBM or compatible computer with hard disk and Hercules, CGA, EGA, or VGA display. \$299.95 plus shipping and handling.

The latest version of this complex and comprehensive astronomy program includes an animation system that allows for real-time movies of stored sky scenes. Every frame of the sequence can have a unique display time, allowing the user to slow down, speed up, or freeze specified frames. The viewer's reference point can also change between frames. Version 3.0a includes the full New General Catalogue of objects as part of its database, and features an improved user interface and the ability to import graphics from other programs and export Genesis scenes to desktop publishing systems. A demo disk of Version 3.0a is available for \$3 in the U.S. and Canada, and \$4 elsewhere. □

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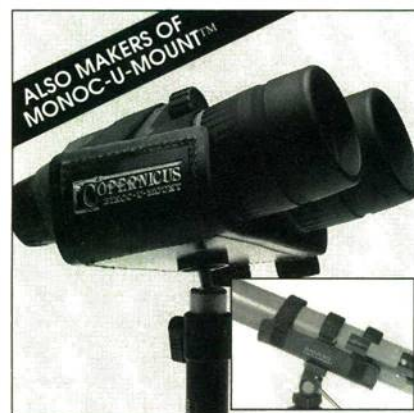
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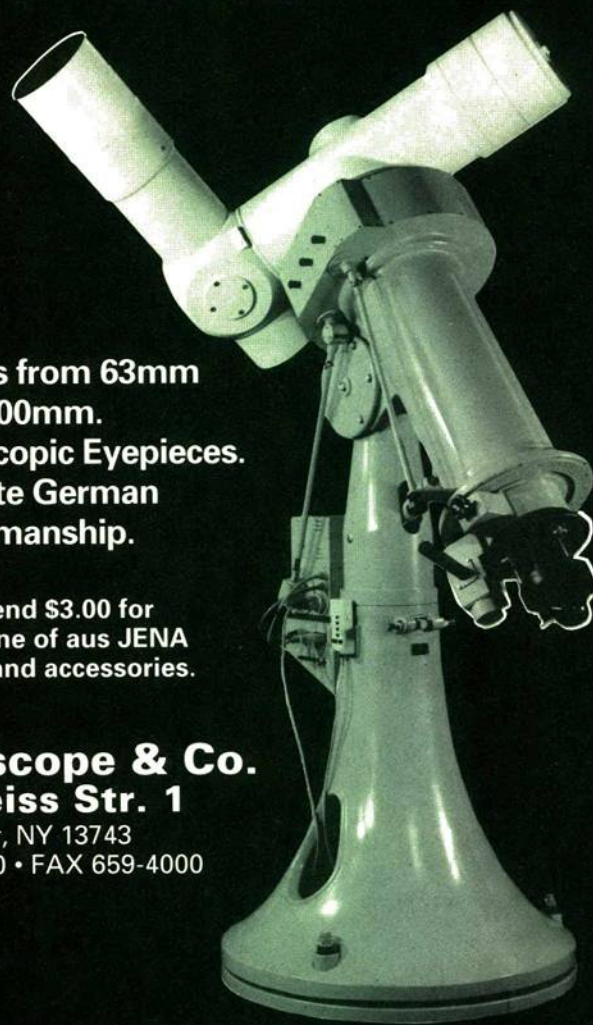
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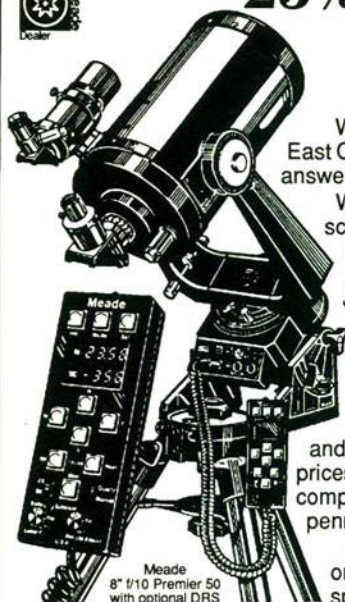
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TELESCOPE INCLUDES:

Optical tube, 2" 1/4" rack & pinion focuser, equatorial mount with RA motor, 8x50 finder, pier & stand, 25mm MA eyepiece



\$824

DS-16AB 16" F/4.5 Newtonian as DS-10A with Sealmaster Mount Bearings **\$1767**

MEADE REFRACTORS

223S - THIS MONTH'S SPECIAL!

This 2.4" 700mm F/11 refractor with 2 eyepieces, diagonal, finder, barlow lens & tripod. Ideal first scope for the kids or even better

\$84.95

use as a inexpensive guide scope

290 2.4 Inch Equatorial

291 2.4 Inch Deluxe Equatorial

312 3.1 Inch Alt-Azimuth

323 3.1 Inch Equatorial

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Meade Series 4000

SUPER PLOSSL - Up to 52° Apparent Field

6.4, 9.7, 12.4, 15, 20, 26mm 1 1/4"

32mm 1 1/4"

56mm 2 inch

2X Barlow 1 1/4" #140

SUPER WIDE ANGLE - 65° Apparent Field

13.8mm 1 1/4"

24.5mm 1 1/4"

40mm 2 inch

ULTRA WIDE ANGLE - 84° Apparent Field

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8.8mm 1 1/4" 2"

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CELESTRON CLASSIC 8 STARBRIGHT

Classic 8 is the latest in a long line of fine Schmidt-Cassegrain telescopes from the company that pioneered top quality commercial scopes. Its fine 8 inch 2032mm F/10 optical tube is further enhanced by the application of Celestron's unique Starbright coating to provide optimum light transmission. Add to that a rugged equatorial mount and accurate motor drive and you have the perfect observing package for any astronomer, pro and novice alike.

FOCUS CAMERA'S EXCLUSIVE PACKAGE INCLUDES:

- 8 inch 2032mm F/10 optical tube with Starbright coatings for enhanced light transmission
- Celestron 24mm Ultima Eyepiece (instead of the lower grade Kellner eyepiece usually supplied)
- Celestron's latest model heavy duty adjustable field tripod (this is usually an additional cost option)

SUPER POLARIS C8

COMPLETE PACKAGE INCLUDES:

8 inch 2032mm F/10 Schmidt-Cassegrain optical tube, Super Polaris equatorial mount with slow motion controls, 5x24 finder, 1 1/4" diagonal 25mm Kellner eyepiece & trunk case.

List Price Over \$1700

\$969



SUPER POLARIS C8 STARBRIGHT

POWERSTAR PEC

The new Powerstar PEC features Celestron's famed 8 inch Schmidt Cassegrain optics with Starbright coatings, PEC periodic error correction DC servo drive system & Byers worm gear for improved tracking accuracy, 30mm Plossl eyepiece, 6x30 finderscope 1X" Star Diagonal, case, wedge & rubberized tripod

\$1539



ULTIMA 8 PEC

The state of the art 8 inch Schmidt Cassegrain telescope from Celestron. It features a rugged swing fork mount with carrying handles for ease of set up, a massive cast polar shaft with 4" ball bearings, 7 1/2" Byers worm gear drive & PEC periodic error correction drive system for the ultimate in drive accuracy.

COMPLETE FACTORY PACKAGE INCLUDES: 8 inch 2032mm F/10 optical tube with Starbright coatings, PEC drive system with hand controller, 30mm Plossl & 7mm Ortho eyepieces, 8x50 Polar illuminated finderscope, 1 1/4" Star Diagonal, case, wedge & rubberized tripod

\$1889

ULTIMA 11 PEC

The ultimate 11 inch scope now with PEC drive.

CALL FOR PRICE AND AVAILABILITY C60E REFRACTOR

- 2.4" 800mm F13 Optics
- Equatorial Mount w/Tripod
- 5x20 Finder, 32x Eyepiece
- Star Diagonal, Moon Filter
- Celestron List Price \$498.00

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4 1/2" Equatorial Newtonian w/Tripod, Eyepiece & Finder

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COMPLETE WITH BASE & BATTERIES
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FOCUS CAMERA'S PRICE

CELESTRON ACCESSORIES

- AC adapter (PEC telescopes) 27.95
- Counterweight set 8" 49.95
- DC inverter - lets Classic 8 to work on 12v DC 78.95
- DEC or Focus Motor (Classic/Ultima 8) 79.95
- DEC or Focus Motor (PEC Scopes) 117.95
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- Single Axis Motor Drive SP-C8/6/80/102 159.95
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- Piggyback Mount all 8" scopes 36.95

CALL FOR COMPLETE DISCOUNT PRICE LIST

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- 5, 6, 7, 9, 12mm .96" 36.95
- 5, 6, 7, 9, 12mm 1 1/4" 47.95
- 25mm 2" Orthoscopic 129.95
- 30mm Plossl 1 1/4" 50° Apparent Field 69.95
- 2X Barlow 1 1/4" 40.95
- 2X Barlow 2" 94.95

ULTIMA SERIES EYEPIECES

- 5, 7.5, 12.5, 18, 24mm 1 1/4" 62.95
- 30, 35, 42mm 1 1/4" 96.95
- 45, 60mm 2" 177.95
- 15, 19, 23mm 1 1/4" Wide-Angle 127.95
- 2X Barlow Ultima Series 1 1/4" 68.95

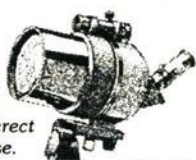
CELESTRON FILTERS

These fine Celestron eyepiece filters can be used with most telescope from most manufacturers.

- .96 Inch: #1A Skylight, #12 Yellow, #21 Orange, #23A Red, #38A Blue, #56 Green, #80A Blue, #96 50% or 25% Neutral Density
- 1 1/4 Inch: #1A Skylight, #8 #12 #15 Yellow, #21 Orange, #23A #25 Red, #38A Blue, #47 Violet, #56 #58 Green, #80A #82A Blue, #96 50% 25% or 13% Neutral Density
- Any of the above filters each 12.95
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- LPR B (rear cell) 108

C90 SPOTTING SCOPES

- 3 1/2" 1000mm F/11 Celestron optics.
- Use as a spotting scope telescope or camera lens
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- C90 MC with multicoated optics 368.00
- C90 Rubberized Multicoated 404.00
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- Eyepieces: 10, 16, 18, 25, 40mm Kellner 32.95



Meade Spotting Scopes

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- 3 1/2" 1000mm F/11 optics
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97ER

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- Camera Adapter .. 34.95 Hard Case 44.95
- Hybrid Diagonal allows use of 1 1/4 eyepieces 48

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- 7x50 FMTRC-SX armored w/compass ... 499.95
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- Motodec DEC Motor for Meade 2080/2120 telescopes 74.50
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Plans for a one-man 17-1/2" Dobsonian using a removable jack assembly method. Breaks down into parts of 40 lbs. or less. Assembles in about 10 minutes from van to viewing. Send \$5 to:

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Observe a NINE-MINUTE Total Solar Eclipse from a chartered jet high over the South Atlantic while enjoying an exciting seven days in Rio de Janeiro, Brazil, starting the last week of June 1992!

Write to Amateur Astronomers Inc.,
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for information on this breathtaking
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New Astronomy Products



1 Sky-Hook Binocular Stand

The Sky-Hook is a binocular mount that allows the user to sit in comfort and observe the sky from horizon to zenith over an angle of 180°. Setup time is claimed to be less than a minute, and once set the stand requires no adjustments of clamps or knobs. Fluid motion of the binoculars is achieved using a combination of nylon rollers and Teflon gaskets and bushings. The Sky-Hook is designed for use with large 80mm aperture binoculars.

Star Bound, 68 Klaum Avenue, N. Tonawanda, NY 14120, (716) 692-3671, FAX (716) 693-8713. \$345 plus shipping and handling.



3 A Designer Observing Chair

The "Chairiot" is an adjustable height, folding astronomer's chair. Its design allows the seat to be adjusted in height from 16 to 30 inches but the chair can be folded down to a package 1-inch thick. Hand made of northern hard maple, the Chairiot is available in matte black or natural finish. It weighs 13.25 pounds.

Architectural Arts, 1903 Appianway Drive, Little Rock, AR 72204, (800) 522-6416, FAX (501) 372-6564. \$79.95 plus shipping.



2 New Accessories from Celestron

Celestron's new 2-inch star diagonal allows the attachment of 2-inch eyepieces and accessories to Schmidt-Cassegrain and refractor telescopes. Unlike other 2-inch diagonals that use mirrors, this one uses a giant prism. The multi-coated prism is said to yield a 15-percent higher light transmission than conventional mirror diagonals, without introducing color aberration. The prism also closes the telescope tube, preventing dust and moisture from entering. It comes with an adapter for 1 1/4-inch eyepieces.

The Micro Guide eyepiece is a multi-coated 12.5mm Abbé Orthoscopic that features a laser-etched reticle with built-in cordless illuminator. It is claimed to have an eye relief sufficient to allow viewing the reticle even with eyeglasses on. The reticle pattern allows for guiding on stars not in the center of the field.

Celestron International, 2835 Columbia Street, Torrance, CA 90503, (800) 421-1526 or (213) 328-9560. Two-inch diagonal: \$410, Micro Guide eyepiece: \$250. A new Celestron Accessory Catalog is available for \$2.



This department presents new product announcements issued by their manufacturers. The product information is as supplied by the manufacturers or distributors. All prices are suggested retail. Suppliers are invited to send their product announcements to the attention of Alan Dyer.



4 Combination Backpack and Chair

Called the "Carry/Tarry," this backpack unfolds to form a seat, a combination useful for astronomy and other outdoor activities. The cushioned seat, supported by steel tubing, can hold a claimed 250 pounds. The backpack itself is made of waterproof material and has zippered pockets.

L.A. Sack, 39 East 20th Street, New York, NY 10003, (212) 477-4300. \$59.95. Available in black, navy blue, red, yellow, and purple.

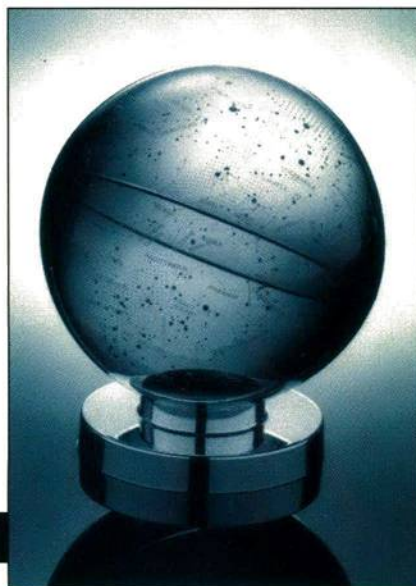
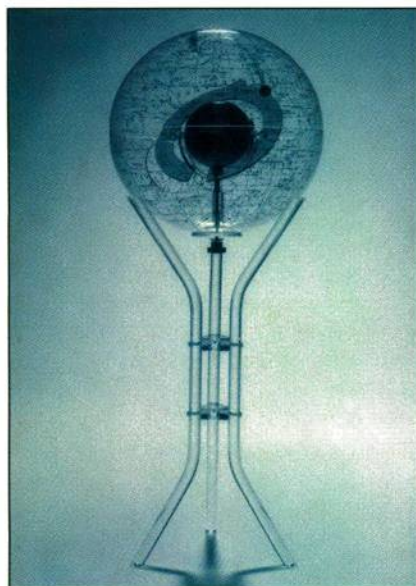
5



Eclipse Medallions

This .999 fine silver medallion commemorates the July 11, 1991 solar eclipse. Each medallion comes with a protective airtight holder and a stand.

Coram Investment Company, 8863 Greenback Lane, Suite #111, Orangevale, CA 95662, (916) 967-0922. \$19.95 plus \$3 shipping. Outside the United States add \$5. California residents add 7.25% sales tax.



6

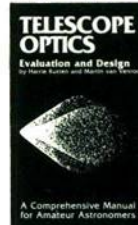
Gift Ideas from the Black Forest Observatory

Two new clear acrylic celestial spheres are available from the Black Forest Observatory. The "Starship Earth" sphere (left) features a rotatable Earth inside a celestial globe. It can be used to show the sky for any date and hour. The 5-inch-diameter "Star Ball" (right) features all 88 constellations and comes with a brass-toned base.

Also available are videocassettes of individual episodes of the *Cosmos* TV series and gift packs of 4 or 5 episodes. The BFO is the only supplier of partial sets of this type. A complete set of 14 episodes that includes the *Cosmos* book is also offered.

Black Forest Observatory, 12815 Porcupine Lane, Colorado Springs, CO 80908, (719) 495-3828. Starship Earth sphere: \$274.95 (16-inch desktop version), \$369.95 (16-inch floorstand version), \$995 plus \$99 shipping (30-inch-diameter floorstand version). Star Ball sphere: \$29.95 plus \$5 shipping. *Cosmos* individual episodes: \$19.95 plus \$5 shipping and handling per order. Gift pack A (episodes 1-5): \$79.95, Gift pack B (episodes 6-9 with *Cosmos* book: \$79.95, Gift pack C (episodes 10-14): \$79.95, complete set with book: \$199.95.

GREAT "HOW-TO" BOOKS



Are you considering buying or building your own telescope? The type of telescope that will be best for you depends upon many factors. ☐ **Telescope Optics, Evaluation and Design** \$24.95 starts with the basics and goes on to explain the advantages and disadvantages for practically every type of telescope of interest to the amateur—the ☐ **Optional IBM-PC Telescope Design Software** \$24.95 check here ☐ for math coprocessor version. (sold only to purchasers of the book) enables you to design and raytrace your own custom telescope. If you decide to make a Newtonian or

Cassegrainian telescope ☐ **How to Make a Telescope** \$19.95 has, for more than 30 years, been consistently rated as the most complete and accurate book on the subject. ☐ **Microcomputer Control of Telescopes**, \$19.95 is a comprehensive guide that provides both the theoretical and practical considerations to computer control of telescopes. For nearly 20 years and 200+ issues the *Makoslov Circulares* covered a wide variety of topics of interest to the advanced amateur telescope maker. The best of these articles have been assembled into **Advanced Telescope Making Techniques**. ☐ **Volume 1—Optics**, \$19.95, ☐ **Volume 2—Mechanical**, \$19.95.

For less than the cost of two rolls of processed color film ☐ **Astrophotography**. Featuring the *fx* System of Exposure Determination,

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has enabled him to make world class planetary photographs from his home in Coral Gables, Florida. This book won the Astronomical Society of the Pacific's "Book of the Year" award for 1989 plus it has the added

bonus of describing the whole range of planetary and lunar observing methods. ☐ **CCD Astronomy. Construction and Use of an Astronomical CCD Camera**, \$24.95 describes CCD cameras in such detail that you can build and program your own camera—or learn the details that will enable you to make an intelligent purchase of a commercial camera. ☐ **Introduction to Astronomical Image Processing. A Comprehensive Guide to CCD Image Enhancement for the IBM-PC and Compatibles**, \$29.95 is for you if you have an IBM-PC with a CGA, VGA or EGA monitor—you can explore the fascinating world of image processing with this book-software combination. The manual is clearly written and images are provided to practice on. Written in MS-QuickBASIC both



executable and source code files are provided. Have you ever wanted a good star atlas that was big enough to be useful but small enough to tuck away in a suitcase, briefcase or even under the seat of your car? Wil Tirion's new ☐ **Bright Star Atlas 2000.0**, \$9.95 is just that kind of atlas. It plots the entire Yale *Bright Star Catalog* plus a selection by Brian Skiff of the Lowell Observatory of 500+ Deep sky objects—including all the Messier Catalog—that are visible with binoculars or small telescope. Once you

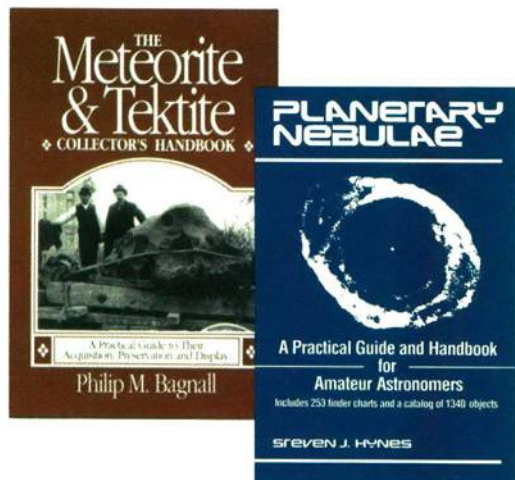
have learned your way around the night time sky there is no better atlas than the World acclaimed *Uranometria 2000.0*. ☐ **Volume 1, The Northern Hemisphere to -6 degrees** \$39.95, ☐ **Volume 2, The Southern Hemisphere to +6 degrees** \$39.95. Together these two volumes plot more than 330,000 stars and 10,000+ deep sky objects. In addition to the titles listed here, Willmann-Bell publishes many other books. Further, we carry well over 1,500 astronomy related titles from other publishers. Our catalog is free with an order but the ☐ **Willmann-Bell Catalog by itself is \$1.00**

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What's New

The Meteorite & Tektite Collectors Handbook At last! Experience the fun of actually collecting meteorites and tektites with this helpful how-to guide. You'll learn to identify, preserve and display these celestial treasures while becoming an expert on composition, structure and classification. Study the history of meteorite collecting and get the inside track on how they are priced and sold. Indexed by subject, meteorites and names for quick and easy reference. Fully illustrated with 38 photos, 24 drawings and 25 tables. By Philip M. Bagnall. 170 pgs., hrbd. #30252/\$24.95

Planetary Nebulae: A Practical Guide and Handbook for Amateur Astronomers For many years, the nature of planetary nebulae remained a mystery. Now find out for yourself the scientific processes by which our current understanding of planetary nebulae have been derived. This guide explores the ways observation and theoretical research have merged to form our present day comprehension of planetary nebulae. Nearly 200 pages are devoted to a catalogue of 1340 planetary nebulae and 253 finder charts — a complete listing of known planetary nebulae through mid-1990. By Steven J. Hynes. 270 pgs., sftbd. #30253/\$24.95

Astro Library

BEGINNER

1992 Exploring the Universe Calendar Celebrate each month with a full-color, 11" X 14" dramatic astrophoto or painting. A monthly essay tells of celestial events while "The Planets this Month" column lets you know when and where to find the planets. From the publishers of ASTRONOMY. #68066/\$9.95

Atlas of the Solar System Provides the most up-to-date information on all aspects of the solar system. Written in encyclopedic style with over 700 photos, illustrations and diagrams plus numerous maps and tables. By Patrick Moore and Garry Hunt. 463 pgs., hardcover. #30235/\$17.99

Astrophotography A clearly written guide for the beginner. By Barry Gordon. 2nd Ed. 208 pgs., softcover. #30125/\$19.95

Cosmos Based on Carl Sagan's award-winning television series, combining the history of astronomy with a view of mankind and our relationship to the universe. Each chapter corresponds to the related televised episode. By Carl Sagan. 365 pgs., hardcover. #30248/\$34.95

Cosmos Video Series and Book Contains seven, two-hour videotapes, each containing two episodes of the Cosmos series, plus a one-hour discussion between Carl Sagan and Ted Turner of Turner Broadcasting. Also includes the corresponding softcover book, *Cosmos*, described above. By Carl Sagan. Book is 325 pgs., softcover. Videos by Carl Sagan Productions, Inc., 2 hours each, VHS. #30249/\$199.98

The Creation of the Universe Host Timothy Ferris takes you from the Big Bang 15 billion years ago to the frontiers of science today. From PBS Home Video. 92 min. #50000V/\$19.95

The Discovery of our Galaxy Explores the mystery, philosophy and people that created astronomy. The author re-creates the lives and temperaments of the great astronomers and also clearly explains the problems astronomers wrestle with today. By Charles A. Whitney. 308 pgs., softcover. #30250/\$14.95

Exploring the Southern Sky Astronomical observations by the European Southern Observatory in the Chilean Andes. With photos of Supernova 1987A, Halley's Comet and a 4-foot panoramic poster of the Milky Way. By Svend Lausten, Claus Madsen and Richard M. West. 274 pgs., hardcover. #30236/\$45.00

In the Stream of Stars Celebrates an extraordinary collaboration between Soviet and American space artists with nearly 200 dazzling, colorful works of space art and each accompanied by an informative explanation. Also includes an entertaining, historical perspective by Ray Bradbury. Edited by Hartmann, Sokolov, Miller & Myagkov. 183 pgs., hardcover. #30247/\$29.95

The Light Hearted Astronomer A wickedly funny story of buying a telescope and becoming an amateur astronomer. By Ken Fulton. 115 pgs., softcover. #18001/\$7.95

Nightwatch This field guide to the universe provides you with a new, simple method of identifying stars, planets, constellations and nebulae. Chapters cover backyard observing, stargazing equipment, the planets and solar and lunar eclipses. By Terence Dickinson. 160 pgs., hardcover. #30229/\$34.95

Objects in the Southern Sky Twenty colorful slides from the European Southern Observatory in the Chilean Atacama desert with a detailed explanation of each slide. Produced by The European Southern Observatory. #30241SET/\$25.00

The Observer's Sky Atlas Basic guide to the night sky for both the novice and experienced observer. With 50 star charts that include stars visible with the naked eye, binoculars or small telescope. By Erich Karkoschka. 130 pgs., softcover. #30237/\$14.95

Philip's Moon Map This 39" x 26" map shows over 500 features on the near side of the Moon, including landing sites of Surveyor and Apollo spacecraft. New Edition. #30068/\$14.95

Philip's Color Star Atlas Shows all naked-eye stars in beautiful color. With 20 wide-field maps and informative introduction. Ideal for naked-eye, binocular, small telescope and armchair astronomers. By John Cox and Richard Monkhhouse. 40 pgs., softcover. #18038/\$19.95

The Quick Reference Guide to ASTRONOMY Magazine 1973-1990 A subject listing for easy access to articles, photos and features in ASTRONOMY magazine. By Jack Hobart. 75 pgs. #30226/\$8.00

Rainbows, Halos & Glories Discusses well-known phenomena such as rainbows and halos, plus sun pillars, sun dogs, glories and mirages. Contains over 200 illustrations, including full-color photos, plus detailed figures to help better understand these optical mysteries. By Robert Greenler. 195 pgs., softcover. #30243/\$22.95

Space Places A unique portrait of how far we have traveled and what lies ahead in space exploration. Lavishly photographed and insightfully written, this book is a personal evocation of the people and technology in modern astronomy. By Roger Ressmeyer. 208 pgs., hardcover. #30232/\$45.00

The Star Book Teach yourself the stars and constellations of the night sky — their names, locations and lore. By Robert Burnham, Senior Editor of ASTRONOMY. 17 pgs., softcover. #18002/\$9.95

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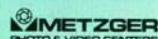
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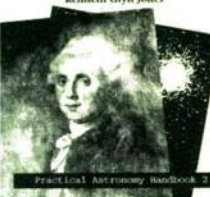
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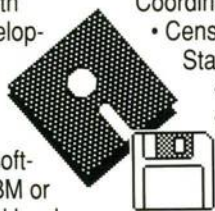
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Readings and Resources

Pulsar Planet (page 30)

"A Planet Orbiting the Neutron Star PSR1829-10," M. Bailes, A. G. Lyne, and S. L. Shemar, *Nature*, vol. 352, pages 311-313; July 25, 1991. The original discovery report. The letter by Helfand and Hamilton suggesting the planet is actually a plasma cloud is in the August 8 issue (page 481) and the reply to them by Lyne is in the August 15 issue (page 573).

"The Origin of the Planet Orbiting PSR1829-10," Ph. Podsiadlowski, J. E. Pringle, and M. J. Rees, *Nature*, vol. 352, pages 783-784; August 29, 1991. This paper describes the models mentioned in the text (two-white-dwarfs-collide and pulsar-cannibalizes-star) for the origin of the planet. On page 763 of the same issue is a letter by Peter Dawson (of Trent University) describing a possible means of turning a supermassive white dwarf into a pulsar without a supernova explosion, thus preserving any planetary system it might have had as a white dwarf.

The Picture of Quasars (page 34)

The Astronomers by Donald Goldsmith, (St. Martin's Press, 1991). Chapter nine of this companion volume to the PBS series describes quasars and their relationship to peculiar galaxies.

Mysteries of the Moon (page 50)

Lunar Sourcebook by Grant Heiken, David Vaniman, and Bevan French (Cambridge University Press, 1991). A detailed summary of lunar knowledge for the professional scientist, but containing overview chapters fairly accessible to lay readers.

Galaxies of Sculptor (page 84)

Burnham's Celestial Handbook by Robert Burnham, Jr., (Dover Publications, 1978). An excellent three-volume set that contains extensive observing notes on a wide variety of deep-sky objects. The section on Sculptor contains eleven pages of data, photographs, and text describing the galaxies and other objects in the constellation.

CREDITS

Cover: painting by Paul DiMare; **p. 4:** NASA; **p. 22, top:** NASA/JPL; **bottom:** NASA/ESA; **p. 26:** courtesy National Radio Astronomy Observatory; **pp. 30-31:** painting by Bob Eggleton; **p. 32-33:** chart plot provided by Andrew Lyne, Jodrell Bank; **p. 33:** photo by G. T. Sina-gola; **p. 34:** painting by Michael Carroll; **p. 36:** x-ray image courtesy Center for Astrophysics; optical image courtesy National Optical Astronomy Observatories; radio image courtesy National Radio Astronomy Observatory; **pp. 36-40:** computer illustrations by Thomas L. Hunt after Belinda Wilkes; **p. 43:** Dana Berry; **p. 44:** National Optical Astron-omy Observatories; **p. 45:** Dana Berry; **p. 46:** painting by Adolf Schaller; **p. 47:** painting by Ernest Norcia; **p. 48:** illustration by Tom Miller; **pp. 50-51:** painting by James Hervat; **pp. 52-55:** photos courtesy NASA; **p. 60, top:** Andrew Steinbrecher, 16-inch f/5.5 reflector, Ko-dachrome 64 film, 1/125-second exposure, July 16, 1981; **bottom:** Patti L. Keipe; **pp. 61-67:** all computer illustrations by Patti L. Keipe; **pp. 68-75:** Chris Becker and Darla Gawel-ski; **pp. 76-77:** computerized map by Thomas L. Hunt after U. S. Naval Observatory Circu-lar 176; **p. 77:** Ed Leikam; **p. 79:** computerized map by Thomas L. Hunt; **p. 79:** Darla Gawelski; **p. 80:** line art by Lee Vande Visse; **p. 81:** Darla Gawelski; **p. 84, top:** Steve Quirk, 10-inch f/6 reflector, hypersensitized Ektar 1000 film, 20-minute exposure; **bottom:** Kim Zussman, 14.5-inch f/8 Cassegrain, hypersensitized Tech Pan film, 115-minute expo-sure; **p. 85:** Scott Hicks, 12.5-inch f/5 reflector, Kodachrome 400 film, 20-minute exposure; **p. 86:** Anglo-Australian Telescope Board; **p. 87:** Anglo-Australian Telescope Board; **p. 89, top:** Debbie Kutner, 55mm f/2.8 lens, Kodachrome 1600 film, 1-minute exposure from the north rim of the Grand Canyon, Arizona, August 13, 1991; **bottom left:** David R. Scherp-ing, 50mm f/2.8 lens, Ektar 1000 film, 8-minute exposure from Gallatin, Tennessee, August 12, 1991; **bottom right:** Jonathan Sabin, 28mm f/2.8 lens, Ektar 1000 film, 8-minute expo-sure from Bradenton, Florida; **p. 90, top left:** Ron Lee, 28mm f/16 lens, Ektachrome 64 film, 24-hour exposure taken in December 1979 from Thule Air Force Base, Greenland; **p. 90, upper left:** Jeffrey L. Jones, 8-inch f/10 SCT, hypersensitized Tech Pan film, 10-minute ex-posure on August 11, 1991; **lower left:** Gerald Rhemann, 6.3-inch f/3.3 Takahashi tele-scope, hypersensitized Tech Pan film, 30-minute exposure on August 8, 1991; **bottom:** David Roles, SCT, Tech Pan film, exposures made on May 29, 1991; **right:** Michael Stecker, 8-inch f/4 Takahashi telescope, hypersensitized Tech Pan film, 15-minute expo-sure; **p. 91:** Jay J. Brausch, taken on July 9, 1991, from Glen Ullin, North Dakota; **p. 92, top:** Jay J. Brausch, taken on July 13, 1991, from Glen Ullin, North Dakota; **left center:** Maurice Gavin, 10-inch f/4 reflector, SBIG ST-4 CCD camera, 3-minute exposure on May 10, 1991; **bottom left:** Chris Highlen and Phil Hudson, 3-inch f/3.8 lens, SBIG ST-4 CCD camera, 3-minute exposure on May 21, 1991; **right:** Gerd Bahr-Vollrath, 8-inch f/10 SCT, hypersen-sitized Fujichrome Super HG 400, two 10-minute exposures printed by integration.

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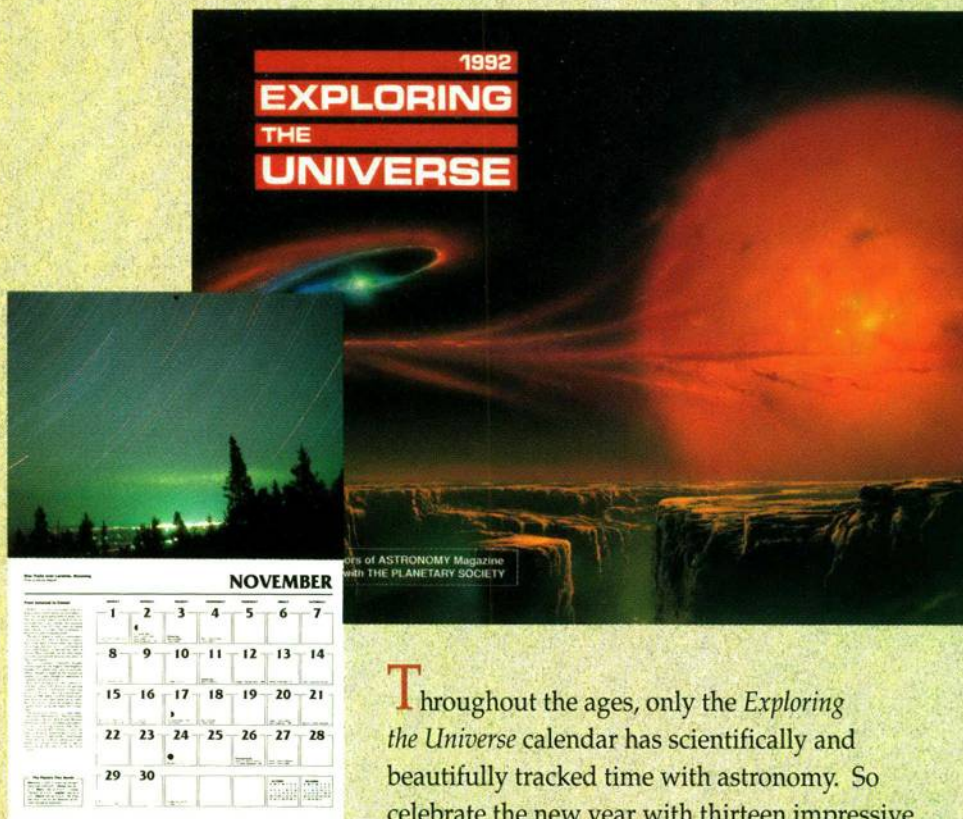
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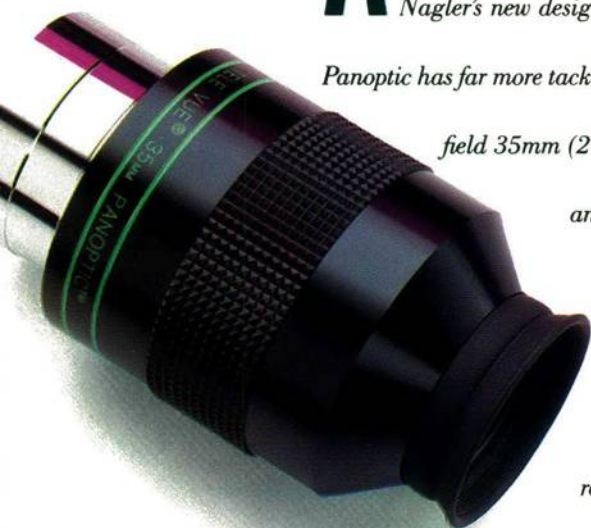
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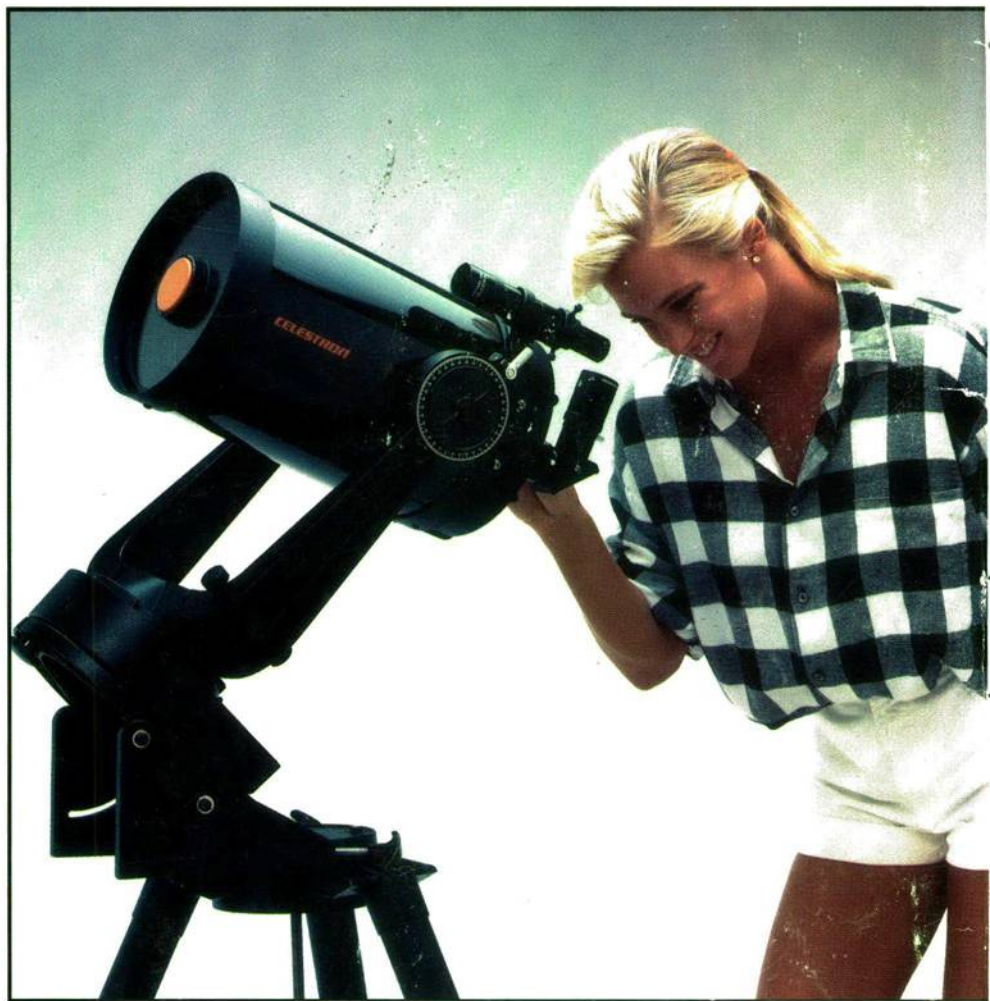


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